The Effect of Mindfulness Meditation on ERP Measures of Attention.

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Statement of Sources

I declare that this report is my own original work and that contributions of others have been duly acknowledged.

_____ Date: …./…./….

James Brady

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Abstract

Mindfulness meditation refers to the non-judgmental and present focus on thoughts, feelings and experiences. Neurocognitive studies have associated processes involved in mindfulness meditation with neural networks implicit in attention. These processes are described in Attention Network Theory. The literature reflects growing support for the use of mindfulness meditation as an attentional intervention. Recent innovation has seen the development of neurofeedback devices, designed to augment the outcomes of mindfulness meditation training. However, there are few studies which have quantified these effects. The Attention Network Test is well-supported in assessing measures of attention outlined by Attention Network Theory. Accordingly, we use the Attention Network Test to compare reaction time (ms), accuracy (% correct), and N1 and P3 ERPs (μV) to quantify the effects of mindfulness meditation relative to an active electrodermal-assisted relaxation control. Results indicate no significant improvement in RT for the meditation group relative to controls, or significant corresponding N1 or P3 amplitudes. However, relating to stable reaction time measures, we find evidence of enhanced attentional network efficiency in the meditation group. These observations are paired with state and trait-based self-reports of disposition, in order to track the intervention's manipulation. We found increased self-reported emotional regulation in both groups. Additionally, we present a case for the use of mixed models in such designs. We conclude that further research is warranted to investigate underlying mechanisms of meditation on attention, and the influence that any dispositional variation may have on training outcomes.

Mindfulness meditation (MM) refers to the non-judgmental and present focus on thoughts, feelings and experiences (Fujino, Ueda, Mizuhara, Saiki, & Nomura, 2018). Neurocognitive MM studies have associated sustaining and shifting mental focus, and disengaging from thoughts with neural networks implicit in attention (Malinowski, 2013). Respectively, these processes are associated with frontal and posterior cortices, frontal eye fields and parietal areas, and cingulate cortex activation (Boccia, Piccardi, & Guariglia, 2015). These cortical regions correspond with attentional subnetworks (alerting, orienting, and executive) defined in Attention Network Theory (Posner & Petersen, 1990; Fan, McCandliss, Fossella, Flombaum, & Posner, 2005). Accordingly, MM may enhance attendance and shifting to, and the governance of, acute outcome-salient stimuli (Chiesa, Calati, & Serretti, 2011; Jha, Krompinger, & Baime, 2007). Real-time quantification of cortical activity through encephalographic (EEG) feedback ("neurofeedback") devices may enhance individual likelihood of attaining meditative states (Crivelli, Fronda, & Balconi, 2019). Knowledge of attention-building interventions has implications for neurodysfunctional and neurodegenerative conditions such as Attention Deficit Hyperactivity Disorder (Mitchell, Zylowska, & Kollins, 2016), dyslexia (A. Matthews & Martin, 2015), and dementia (Firbank et al., 2016).

Attention Network Theory

Attention Network Theory describes three interrelated subnetworks, discrete in function and structure (Fan et al., 2009), which underpin attentional resource allocation; the alerting, orienting and executive networks (Posner & Petersen, 1990). The norephinephrine-primed alerting network governs vigilance and arousal to stimuli (Fan et al., 2009). It comprises tonic and phasic alertness. Tonic alertness sustains the baseline environmental watchfulness responsible for identifying

unanticipated events (e.g., global cues monitoring; Britton, Lindahl, Cahn, Davis, & Goldman, 2014). Phasic alertness refers to the rapid priming of attentional resources triggered by forewarning of stimuli (e.g., cued targets). While phasic alertness readies an acute target response, tonic alertness relays information to subsequent orienting and executive networks. A primed alerting network is considered foundational in attentional task performance (Petersen & Posner, 2012).

The cholinergic orienting network enables re-allocation of visual attention to locational stimuli (e.g., a spatial stimulus; Fan et al., 2009; Petersen & Posner, 2012). Orienting is directed through two dynamic networks (dorsal and ventral) conjoining frontal and parietal cortical regions (A. Matthews & Martin, 2015; Shomstein, Lee, & Behrmann, 2010). The ventral system directs involuntary focal shifts to exogenous (bottom-up) stimuli (e.g., identification of random cues), whereas the dorsal system facilitates voluntary, endogenous (top-down) attentional re-allocation (e.g., focal shifts to goal-salient targets). Accordingly, the orienting network is a conduit for information selection (Posner & Rothbart, 2007).

The higher-order dopaminergic executive network controls stimulus processing through top-down negotiation and resolution of conflict, facilitated by the anterior cingulate and dorsolateral prefrontal cortices (Fan et al., 2009). Integral to error detection, the executive may also be related to thoughts, feelings and response demands (Posner & Rothbart, 2007). Researchers may quantify the executive effect by manipulating task set, commonly achieved through burying goal-salient targets among prominent and misleading distractors (Fan et al., 2009; Neuhaus et al., 2010; Petersen & Posner, 2012). Such paradigms include the Oddball Task (West, Schwarb, & Johnson, 2010), Stroop Test (Scarpina & Tagini, 2017), and Eriksen Flanker Task (Eriksen & Eriksen, 1974). As executive dysfunction leads to poor

performance in such tasks (Scarpina & Tagini, 2017), the executive network may be considered the waystation of informed action.

Neuroimaging studies have identified two additional, functionally opposed networks; salience and default mode (Malinowski, 2013). Where the dorsal orienting network shifts focus to the contextually germane, the monitoring and top-down detection of such stimuli is conducted through the salience network (Malinowski, 2013; Sridharan, Levitin, & Menon, 2008). The default mode network is associated with mind-wandering, or endogenous focus. While it is important to acknowledge the presence of these networks (Malinowski, 2013; Sridharan et al., 2008), the present study intends to build on the canonical tripartite attentional theory (Posner & Petersen, 1990).

Attention Network Test

The ANT, as described by Fan et al. (2009), engages discrete networks outlined in Attention Networks Theory (Posner & Petersen, 1990). Combinations of ANT cue and flanker components elicits varying behavioural responses, measured by RT and accuracy (Fan et al., 2009; Neuhaus et al., 2010; see Figure 1). Integration and/or differentiation of attentional network effects can be contrasted with these data. Attention is sustained on a central fixation point before one of three transitory cue types (No/Centre/Double/Spatial) is presented. Cues indicate an impending target; a central arrow buried amid four like-flankers which are congruent or incongruent with the target's direction (left/right). Correct indication of the target's direction constitutes an accurate response.

Temporal forewarning provided by double (above/below fixation) and centre cues activates the phasic alerting network, whereas valid locational and temporal indications by spatial cues (above/below fixation) primes the orienting network (Fan

et al., 2009). Indications are not provided by no cue trials. Target detection and conflict negotiation of incongruent flankers activates the executive network. Behavioural performance increases with the informativeness and reliability of cues, ordered by fastest RTs they are; spatial, central/double, and no cue. As bottom-up processing is vulnerable to conflicting stimuli, slowest RTs are found with incongruent flankers (Fan et al., 2009).

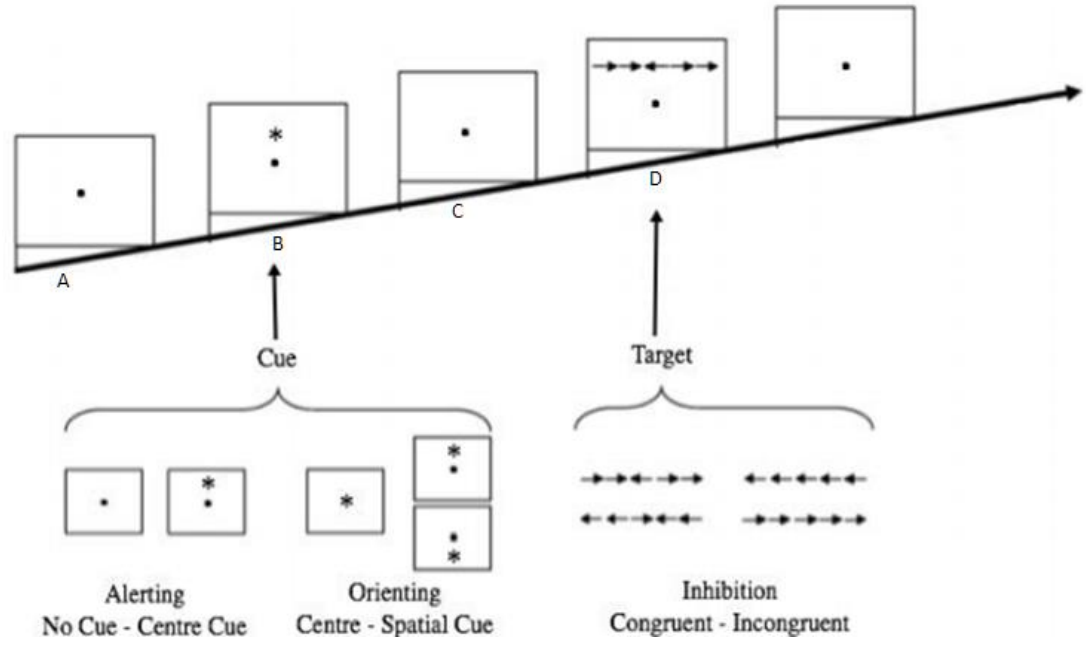

Figure 1. The ANT framework (adapted from Neuhaus et al., 2010). A) 400ms, B) 100ms, C) 400ms, D) 1000ms (randomised between 1000ms-1300ms).

Network effects refer to the mean difference between respective cue and flanker RTs. Double and no cue differences constitutes the alerting effect, whereas the orienting effect is found between spatial and centre cues. Greater differences indicate larger network effects. The converse is true of executive effects, for which mean congruent RT is subtracted from mean incongruent RT (Neuhaus et al., 2010). Observed effects are 45ms, 52ms and 100ms, respectively.

Double cue trials are intended to diffuse attention between spatial locations (Fan, McCandliss, Sommer, Raz, & Posner, 2002). However, diffuse attention is also anticipated with centre cues. Due to this overlap, recent studies replaced double cue

with centre cue-only trials (Harris, 2016; Stone, 2018). This shortens the ANT for participants and simplifies analyses.

Mindfulness Meditation

Meditation stems from Buddhist culture and comprises many subtypes; the practice of which may build emotional and attentional regulation (Lutz, Slagter, Dunne, & Davidson, 2008). Mindfulness refers to a state- or trait-based disposition relating to clarity of thought and self-regulation (Sørensen et al., 2018). MM comprises two attentional practices: focused attention (FA) and open monitoring (OM; Lutz et al., 2008). FA refers to concentration on a stimulus (e.g., the breath), OM refers to the release of focus and passive moment-to-moment observation (Lutz et al., 2008). Common MM practices include Mindfulness-Based Stress Reduction (MBSR) and Mindfulness-Based Cognitive Therapy (MCBT; (Gallant, 2016).

Cross-sectional studies reveal elevated levels of state mindfulness (Bergomi, Tschacher, & Kupper, 2015), and neural network efficiency (Kozasa et al., 2011), in meditators relative to non-meditators. These studies are limited, as causality cannot be inferred; idiosyncrasies may entice people to meditate, or practice more diligently (Tang, Holzel, & Posner, 2015) Longitudinal studies are favoured as they enable participant randomisation (Tang et al., 2015). However, lack of training adherence, participant drop-off, and cost may limit such designs (Cavanagh et al., 2018; Fish, Brimson, & Lynch, 2016). Accordingly, much longitudinal MM research varies in intervention duration; from five-day, 100-minute designs (Tang et al., 2007), to 16-week, 19-hour designs (Moore, Gruber, Derose, & Malinowski, 2012). While there exist mixed findings regarding the efficacy of MM for cognitive augmentation, there is growing support in its favour (Chiesa et al., 2011; Raffone & Srinivasan, 2017).

Neurofeedback may aid MM training outcomes through operant conditioning and/or trial-and-error learning (Balgemann, 2015; Crivelli et al., 2019). The MUSE™ (InteraXon Inc) is a non-invasive EEG headband which provides audial neurofeedback through a mobile MM training app. Calm sounds represent cortical placidity, a which become stormy with cognitive disturbances (Crivelli et al., 2019). Indications meditative states are processed through an undisclosed algorithm. Notably, MUSE™ logs days and minutes of practice, which may addresses limitations of subjective adherence self-reports found in similar training studies (Wahbeh, Zwickey, & Oken, 2011).

Mindfulness Meditation and Attention Networks

Sustaining and shifting mental focus, and disengaging from intrusive thoughts during MM is associated with the alerting, orienting and executive networks respectively (Malinowski, 2013). A systematic review found reportedly enhanced executive and orienting performance after MM training (Chiesa et al., 2011). Executive enhancement was found using a population of school children and the ANT (Tang et al., 2007), evidenced by significantly lowered incongruent flanker interference on RT, relative to congruent flankers, after five days' MM training, compared to controls.

A systematic review found executive improvements (improved incongruent RTs) from early stages of MM training, alongside improved spatial cue performance (Orienting Network) during the ANT (Chiesa et al., 2011). Another study using the ANT found improved Alerting following Central Cues in participants who engaged in an intensive meditation retreat (Jha et al., 2007), however significant differences for Centre Cue RT after meditation interventions are not widely supported by the literature (Leonard et al., 2013; Tang et al., 2007).

Commonalities exist between brain regions activated by MM and those used in Attention Networks Theory (Marchand, 2014; Petersen & Posner, 2012). An activation likelihood estimation meta-analysis of fMRI studies found increased activity during MM in the prefrontal cortex, cingulate cortex and parietal areas (Boccia et al., 2015). These areas relate to the Alerting, Executive and Orienting Networks respectively. Structural MRI and fMRI studies have found that MM can enhance activation and contribute to greater cortical thickness in brain regions associated with attention (Tang et al., 2015). The effects of these regions have further supported the role of frontal brain regions in executive attention, such as the cingulate and prefrontal cortices (Fan et al., 2009). These observations link structural and functional changes associated with MM to enhanced attentional performance.

Cross-sectional studies comparing meditators to non-meditators consistently reflect improved behavioural performance in tasks requiring Executive attention, specifically inhibition, such as the Stroop test (Chan & Woollacott, 2007; Malinowski, 2013), however some studies have failed to replicate similar findings from longitudinal intervention studies (Anderson, 2007).

Chan and Woollacott (2007) posit that improved Executive task performance for meditators may be mediated by higher levels of emotional regulation, that interfering emotional fluctuations occur when participants engage with research and that subsequent effects on performance are suppressed by meditators' ability to regulate how they feel. Other cross-sectional studies have found significant structural effects of meditation tied to regions involved in attentional networks (Kang et al., 2013; Luders, Cherbuin, & Kurth, 2014). The literature commonly reflects denser cortical thickness in the frontal brain regions associated with Executive attention and Alerting. Luders et al. (2015) also found thicker densities bilaterally in the parietal

area, which is involved in Orienting and Alerting, and the cingulate cortex, also involved Executive networks. However, the latter findings were not shared by Kang et al. (2012), where thinner parietal-occipital areas (alerting/orienting) were found in meditators. Research has shown increased functional connectivity in regions associated with attentional networks (Hasenkamp & Barsalou, 2012), and experienced meditators have shown better alpha band integration during EEG studies reflecting enhanced network connectivity compared to non-meditators (van Lutterveld et al., 2017). This suggests there exist structural, functional and connectivity differences in attention between meditators and non-meditator populations.

Longitudinal studies cater for individual differences by controlling for known mediators of interventions through use of naïve participants. While findings are varied on whether MM training improves Orienting performance, the literature consistently reflects enhanced Executive-related behavioural performance in meditation groups (Ainsworth, Eddershaw, Meron, Baldwin, & Garner, 2013; Becerra, Dandrade, & Harms, 2017; Semple, 2010). Significant effects of MM on Alerting performance are, again, uncommon (Jha et al., 2007). A study using novice meditators found improvements in Orienting and Executive control in the ANT for those who had been assigned to an eight-week daily MM intervention (Becerra et al., 2017). A randomised week-long MM retreat also yielded greater Executive attentional effects in an ANT-like flanker task (Elliott, Wallace, & Giesbrecht, 2014), the results also suggest that the performance of the Executive attention network was decoupled from the Alerting network. No effect of MM on orienting was found. A randomised intervention also found improved Executive control, measured by the ANT, in novice meditators who had been assigned to three one-hour sessions of FA

or OM (elements of MM; Lutz et al., 2008) training over a period of eight days (Ainsworth et al., 2013). Despite anticipating an effect on Orienting, no such improvement was found between intervention groups and controls. A study using incarcerated youths and the ANT found that attentional performance benefits gained from a three-to-five week, 750-minute, cognitive-behavioural therapy and mindfulness training course (CBT/MT) remained stable up to four months post-baseline when compared to active controls (Leonard et al., 2013).

Jha et al. (2007) suggest that observed improvements in Orienting performance in the ANT after Mindfulness-Based Stress Reduction training may stem from crossovers between response- and sensory-level stimulus detection during meditation and the voluntary processes involved in the Orienting network. Overall, however, there is a clear lack of agreeance as to whether meditation improves Orienting performance (Polak, 2009; Tang et al., 2007). (Elliott et al., 2014) suggests this may be due to a) lack of orienting task sensitivity, b) subtly, or no, orienting demand in meditation, or c) lack of uniformed interventions and/or analyses. Although studies have largely focused on the cognitive outcomes of meditation, a more elegant understanding of these processes is offered through neurophysiological observations (Crivelli et al., 2019; Norris, Creem, Hendler, & Kober, 2018).

Electrophysiological Measures of Attention

The temporal sensitivity of EEG allows the cellular processes underpinning cognition to be quantified within milliseconds (Neuhaus et al., 2010; Woodman, 2010). Raw EEG signals are averaged by temporally-locked markers to produce event-related potentials (ERPs; Woodman, 2010). ERP waveforms reliably indicate cognitive components, including those relating to Attention Network Theory (Galvao-Carmona et al., 2014; Jo, Schmidt, Inacker, Markowiak, & Hinterberger,

2016). Components such as the N1 and P3 can be elicited through network-defined tasks, such as spatial cues or incongruent flankers, contained in the ANT (Neuhaus et al., 2010).

The extrastriate-generated N1 ERP deflection occurs approximately 140-250ms after target-onset (Neuhaus et al., 2010). Greater posterior N1 amplitudes are indicators of early selective attention, facilitated by orienting and alerting networks. Neuhaus et al., (2010) observed greater N1 ERP magnitudes in order of spatial, then double/centre, and no cue ANT trials. As cues, and not flanker trials, elicit the N1 - as well as pre-conscious attentional blink stimuli (Sergent, Baillet, & Dehaene, 2005) – the component is not implicated with higher-order attentional processing. Functionally, the N1 ERP represents intensified attention and/or visual processing (Reuter et al., 2019).

The P3 component is observed in several cortical regions, and believed to be an expression of a dispersed (Nieuwenhuis, Aston-Jones, & Cohen, 2005). The frontal P3 ERP is generated by the anterior cingulate cortex, with consequential inflections observed approximately 300-650ms after target onset (Neuhaus et al., 2010). Elicited by conflict-laden decision-making, frontal P3 amplitudes scale in magnitude according to the complexity of tasks. These include tasks which require dominant response inhibition, such as Nogo trials (Gajewski & Falkenstein, 2013), and similar high-conflict trials such as incongruent ANT flankers (Neuhaus et al., 2010). Accordingly, the P3 component is regarded as an indicator, or mediator, of discriminatory executive-related attention.

ERP Studies of Mindfulness Meditation

Mindfulness dispositions, associated with MM practice, are considered to influence attentional measures. Lin et al. (2018) reported lower P3 amplitudes for

those higher in FFMQ-rated mindfulness awareness during incongruent ANT flanker trials, relative to those with lower ratings. Accordingly, trait mindfulness may improve attentional network efficiency through attenuating task-based conflict. Considering ANT incongruent flankers, Norris et al. (2018) found greater ratings of Big 5-rated neuroticism marginally reduced posterior P3 amplitudes associated with acute MM exposure (10 minutes), whereas lower levels of neuroticism increased frontal N2 amplitudes (involved in competing responses). This suggests that, while MM may improve attention (Chiesa et al., 2011), levels of neuroticism-related self-awareness and/or anxiety may hinder training engagement and any associated benefits (Norris et al., 2018).

Cross-sectional ERP studies find differences between experienced meditators and naïve control groups. For example, Jo et al. (2016) found higher averages in meditator N1 amplitudes during ANT cues relative to controls. Although both groups expressed significantly elevated frontal P3 amplitudes during incongruent trials, such elevation in the posterior P3 was only observed in controls. As meditators showed stable RTs, and lowered error rates, results may indicate greater focal capacity (N1), and attentional engagement (P3). Atchley et al., (2016) found novice and experienced meditators expressed elevated frontal P3 amplitudes when attending to audial targets, relative to controls. Conversely, this amplitude effect was attenuated when tones were voluntarily ignored. This further demonstrates augmented attentional control in MM practitioners.

Longitudinal ERP studies share similar results with cross-sectional studies, reflecting mixed task performance and modulated ERPs after MM training interventions (Chiesa et al., 2011). However, randomised and/or control-balanced ERP training interventions are relatively scare (Elliott et al., 2014; Singh & Telles,

2015); fewer studies have examined neurofeedback MM interventions using ERP measures of attention (Crivelli et al., 2019).

Avery (2016), used child-based version of the ANT to find increased N1 amplitudes across alerting and orienting conditions (N1), and both flanker types (P3) associated with MM practice. that MM practice elicited significantly higher N1 amplitudes during for orienting cues, suggesting increased attention to the task (Avery, 2016). Another study used a MM-based breathing intervention with meditation-naïve participants over 16 weeks (Moore et al., 2012). It used a Stroop task, paired with ERP recording, to measure behavioural and electrophysiological outcome measures to a control, post intervention. The study found significantly increased posterior N2 ERP amplitude in the MM group. It also found differences in P3, such that meditators elicited decreased amplitudes for Incongruent stimuli when compared to controls. This also suggests that MM training may improve executive network efficiency.

Crivelli et al. (2019) used a four-week neurofeedback MM training intervention, based on Vipassana – starting from 10 minutes a day and increasing to 20 minutes a day, paired with an active breath control group. They used the Maudsley Index of Delay Aversion, and a Stroop type task, which require participants to identify and respond to correct targets in the presence of incongruent information; tests of discrimination and response inhibition. The study reflected improved task performance and significantly elevated N2 ERP amplitudes, when compared to a control group. This, again, may reflect greater executive efficiency in the MM group.

Study Aims and Hypotheses

This study adapted a revised version of the ANT (Harris, 2016) to analyse the electrophysiological and behavioural effects of MM. It is novel in investigating the efficacy of MM using a commercial neurofeedback device, with electrophysiological and behavioural attentional measures elicited by the ANT. An active control group with an electrodermal biofeedback device was used to account for potential technology-related expectancy confounds. It also provides dose-related data on short-term MM training.

As MM is found to enhance early selective attentional processes (Boccia et al., 2015), it was hypothesised that MM training would significantly decrease spatial cue RTs relative to central cue conditions, and to that of controls. Any RT improvement is expected to coincide with greater N1 amplitudes. MM is also found to improve functionality of the executive networks (Chan & Woollacott, 2007). Accordingly, we anticipate MM training to yield significantly faster RTs for incongruent trials, relative to congruent trials, and compared to controls. If so, we expect corresponding increases in P3 amplitude. In failing to observe significant RT improvement, we propose a secondary hypothesis of decreased N1 and P3 magnitudes. Stable RTs over time, with lower magnitude ERPs, should reflect enhanced network efficiency.

Method

Participants

The study recruited 33 right-handed males and females who were allocated, in blocks of four using an online randomisation generator (randomization.com), to Relaxation (n=18) and MM (n=17) groups. To ensure general stability of cognitive function, only participants 18-35 years old were recruited (Hartshorne & Germine, 2015). A control group participant was removed prior to analyses due to

electrophysiological measurement error, removal from behavioural data (accuracy<50% correct), and drop-off. Another control member was removed prior to analyses, due to pre-experimental departure. One MM group member was lost from electrophysiological data (measurement error), and post-training data (non-contribution). The final pool (N=32) fell short of the desired G*Power 3.1.9.2.-estimated sample size (N=40) for detecting moderate within/between interaction effects (f=0.25, β=0.80, α=05). Recruitment occurred via the University of Tasmania's psychology research participation portal, flyers, social media and word-of-mouth (See Appendix A.). Participants were remunerated ($60 giftpay voucher/4hrs course credit and $20 voucher).

Meditators show greater attentional test efficiency (Kozasa et al., 2011), accordingly we recruited only those with low meditation or relaxation experience (no experience/practice<12 months/<5 hours lifetime). Additional exclusion criteria were those with; uncorrected vision/hearing, English as a second language, or a history of neurological/psychiatric disorders. Those who reported illicit drug use (recent), psychoactive medication (current, excepting contraceptive pill), sleep disorders (current), seizures, giddiness or loss of consciousness (minutes>2), daily tobacco use (current), severe head injury, heart or serious physiological conditions, pregnancy or those expecting to be pregnant were also excluded. Elevated levels of psychological distress (score>30) on the Kessler Psychological Distress Scale, (K10; Kessler et al., 2002), and/or susceptibility to alcohol dependence (score>16) on the Alcohol Use and Disorders Identification Test (AUDIT; Babor, Higgins-Biddle, Saunders, & Monteiro, 2001) were additional exclusions.

Attention Network Test

NeuroSCAN Stim2 software was used to present the ANT (Neuhaus et al., 2010). Stimuli were presented as white text on a contrasting black background. The test presents a central fixation point (400ms pre-trial), with a cue; No Cue (fixation unchanged), Central (asterisk; 100ms on fixation), or Spatial (validly cued asterisk; 100ms, 1° above/below fixation). A central arrow with two flankers either side was then presented as a contextually Congruent or Incongruent response target. Arrows appeared 400ms post-cue offset, 1° above or below the stimulus, remaining until a response was made or until 1000ms. Direction of the central arrow was input by arrow keys with corresponding index fingers (left/right). Inter-trial intervals were randomised between 1000ms and 1500ms. Responses above or below 3*SD*s from the individual condition mean were removed.

EEG Measurement

EEG recordings were facilitated by a NeuroSCAN system paired to a 32-channel (Ag/AgCl electrodes) electrode Quik-Cap with 10-20 electrode placement. Continuous activity was recorded at 1000Hz, referenced to linked mastoids, and with electrode impedances<10kΩ. Electrodes on bilateral outer canthi and an upper and lower site around the left eye provided electrooculographic activity data. Offline editing of Oz and Fz data involved a low-pass filter (30Hz, 24dB), electroocular artefact minimisation. Epochs were averaged at 1000ms, beginning 100ms pre-stimulus, before artefact rejection protocols (±70μV), and target-locked averaging of ERP signals to each condition. ERPs represent grand averaged waveform peaks. The N1 is measured as peak negative Oz amplitudes 150ms-250ms post-target onset. The P3 at Fz constitutes peak positive amplitudes 300ms-600ms after target onset.

Questionnaires

Questionnaires include; Cognitive and Affective Mindfulness Scale-Revised (CAMS; Feldman, Hayes, Kumar, Greeson, & Laurenceau, 2007), Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003), K10 Scale (Kessler et al., 2002), Difficulties with Emotional Regulation Scale-18 (DERS; Victor & Klonsky, 2016), Mini-IPIP (Donnellan, Oswald, Baird, & Lucas, 2006), Profile of Mood States Questionnaire (POMS; Curran, Andrykowski, & Studts, 1995), State-Trait Anxiety Inventory (STAI; Spielberger & Gorsuch, 1983), the Mini-IPIP (Donnellan et al., 2006), Weschler Test of Adult Reading (WTAR; Weschler, 2001), Karolinska Sleepiness Scale (KSS; Shahid, Wilkinson, Marcu, & Shapiro, 2011) and Five-Factor Mindfulness Questionnaire (FFMQ; Baer, Carmody, & Hunsinger, 2012).
As MM-related improvements to factors such as emotional regulation (Chiodelli, Mello, Jesus, & Andretta, 2018), and mindfulness (Sørensen et al., 2018), may improve attention, we used the following scales as manipulation checks.

The State-Trait Anxiety Index-Y (STAI) is a 20-question measure of anxiety, measured by two forms; state and trait (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). State-based questions measure present-level anxiety, rated on a four-point Likert-type scale from ‘not at all’ to ‘very much so’. It has high total (a=.96) among psychologically distressed Australian populations (Crawford, Cayley, Lovibond, Wilson, & Hartley, 2011).

The Profile of Mood States (POMS) is a 5-point, 37-item measure of psychological disturbance, or distress (Curran et al., 1995) Measures use single adjectives, indicated from 0 ‘not at all’, to 4 ‘extremely’, according to a participant’s feelings ‘at the moment’. It has high internal validity, and is widely used in medical populations (Baker, Denniston, Zabora, Polland, & Dudley, 2002).

The State Difficulties in Emotional Regulation Scale (SDERS), based on the original DERS (*a*=.90; Victor & Klonsky, 2016), is an 18-question, five-factor scale which measures in-the-moment evaluations of emotional dysregulation (*a*s=.56-.92; Lavender, Tull, DiLillo, Messman-Moore, & Gratz, 2017). Scores are negatively correlated with difficulties.

The Cognitive Affective Mindfulness Scale-Revised (CAMS) is a 12-item Likert measure of mindfulness and emotional regulation (Feldman et al., 2007) It uses a four-point response scale from 1 'Rarely/Not at all' to 4 'Almost always'. It is considered a good measure for interventions, and has good internal consistency (*α*s .74 -.77; Feldman et al., 2007).

The Mindful Attention Awareness Scale (MAAS) is a 15-point Likert measure of trait mindfulness, using six-scale responses from 1 'almost always' to 6 'almost never' (Brown & Ryan, 2003). It is negatively correlated with psychological and mood disorders, such as depression (Osman, Lamis, Bagge, Freedenthal, & Barnes, 2016).

Intervention

Participants were randomly allocated to a 20-minute-a-day intervention condition; MM, using a MUSE neurofeedback headband, or Relaxation, using an iPip electrodermal biofeedback device. Participants were provided with a device at the end of the first experimental session. Experimenters explained relevant training protocols for the MUSE app (Appendix B), or iPip Loom app (Appendix C). Successful device coupling was ensured. The MUSE intervention involved audio-guided neurofeedback-assisted MM a day for seven days. Greater levels of cortical activity were reflected by storm noise, with lower levels reflected by calmer sounds or birds, if a meditative state was achieved. The active control group's practice was

reflected visually, with a winter landscape transitioning into spring. Transition speed was determined by high (slow) or low (fast) skin conductivity, as represented by a reactive (red=high, green=low) indicator. Participants were asked to complete their training in a quiet room, with no distractions.

Procedure

Approval for this study was granted by the University of Tasmania Human Research Ethics Committee (Appendix D). Participants completed online screening measures prior to attending experimental sessions (Appendix E), including pre-training control measures related to personality (Mini-IPIP), trait anxiety (STAI) and total trait mindfulness (FFMQ). Eligible participants were contacted by phone to arrange pre- and post-training experimental sessions, spaced seven days apart. Experiment information was provided to participants on arrival at the pre-training session (see Appendix F), and informed consent was provided. As part of the screening questionnaires (see Appendix G), participants were asked if they had taken illicit drugs since completing the screening survey, if they had recently taken alcohol, caffeine, nicotine, or consumed any other medications. They then completed digital versions of the secondary outcome measures (KSS, STAI-State, POMS, DERS, CAMS and MAAS) before experimenters conducted the WTAR as an estimate of verbal IQ.

EEG setup proceeded, including electrode cap fitting (20-30minutes approx.). Participants then completed the ANT and an emotional Stroop task, randomised in order of participant, and included practice trials and three break spaces if needed. A resting EEG task (eyes open, eyes closed, and focused breathing) was then run, including a pre- and post-induction Visual Analogue Scale (VAS) to measure mood (Ben-Haim et al., 2016; Neuhaus et al., 2010). Breaks were given between each five-

minute block. Equipment was removed, and participants received instructions for their intervention/control activities (20 minutes of MM or Relaxation training each day for one week) and completed a brief outcomes expectancy survey relating to Attention, Emotional Wellbeing and Computer Task proficiency (see Appendix I). The present study was concerned only with the primary behavioural (RT/Accuracy) and ERP outcome measures (N1/P3 components) from the ANT. Stroop and EEG task data are reported elsewhere. The second session ran identically, with repeated questionnaires regarding participant caffeine, illicit/psychoactive drug, nicotine and alcohol intake, and secondary measures (KSS, STAI, POMS, DERS, CAMS, MAAS). Information from the participant's intervention device, including number of days trained, length of total training, intervention app scores and adherence statistics were recorded. Participants were debriefed and remunerated.

Design and Data Analysis

The study used a mixed factorial experimental design with random allocation. Between-subjects IV of Group (Meditation/Relaxation), and within-subjects IVs of Time (Pre/Post), Cue (no/centre/spatial), and flanker Congruency (congruent/incongruent) were analysed with DVs of RT (ms), Accuracy (% correct), and N1/P3 Amplitude (μV). Separate 2x2x3x2 mixed models analyses were run. We used Group x Time mixed models to assess Questionnaire data. Significant main effects, and hypothesised pairwise comparisons (α =.05), were reported. To avoid Type II errors, planned comparisons were unadjusted (LSD) and/or supported by ANOVA. We provide $p_{Bonferroni}$ as a point of discretion for multiple comparisons (n>3; Duricki, Soleman, & Moon, 2016). Unless otherwise stated, non-primary data was contrasted using raw scores and independent samples t-tests. Violations of equality, indicated by Levene's Test of Homogeneity, were assessed using Mann-

Whitney U tests. Hedge's *g* calculations were based on cell means and *SD*s (Rosenthal & Rosnow, 2008), with effects interpreted as 0.20 (small), 0.50 (moderate),>0.80 (large; Cohen, 1988). Linearity was assumed, as indicated by anticipated and observed directional effects, and extreme outliers were identified via boxplot, and their influence on main effect outcomes was assessed. We anticipated moderate departures from normality, due to retention of incomplete data, but persevered with mixed models. We assumed central tendency test robustness, and refer to Norman (2010).

Results

The resilience of mixed models allowed us to maximise our observations (Woltman, Feldstain, MacKay, & Rocchi, 2012), and retain three electrophysiological ($n_{pre=}2$, $n_{post=}1$) and one behavioural datapoints (n_{pre}=1). We had uneven, yet unbiased, pools for electrophysiological (n_{relax}=16, n_{meditate}=15), behavioural (n_{relax}=16, n_{meditate}=16), and questionnaire (n_{relax}=16, n_{meditate}=16) observations. Maximum Likelihood estimation was used to compare models and balance covariance parsimony against goodness-of-fit (χ^2_{change}; see Table 1). Where applicable, fixed factors of Group, Time, Cue and Congruency, and participant-nested repeated factors of Time, Cue and Congruency applied. Compound Symmetry (CS) and Unstructured models for each repeated measure were compared. Calculation of $\chi 2_{\text{change}}$ occurred through Microsoft Excel 2019, using =CHISQ.DIST.RT(x,deg_freedom) syntax. Consideration of BIC was given while observing significance output, which helped identify the CS model as best-fit for all analyses. LSD adjustment and the default IBM SPSS v.23 MIXED *df* Satterthwaite approximation were applied.

Table 1.

Model fit statistics for Compound Symmetry and Unstructured covariances, and goodness-of-fit analyses for experimental DVs.

	Compound Symmetry		Unstructured		Model Fit_{change}	
DV	$\chi^2(df)$	BIC	$\chi^2(df)$	BIC	$\chi^2(df)$	p
CAMS	347.30(6)	372.16	347.05(7)	376.05	0.25(1)	.617
MAAS	127.29(6)	152.15	126.95(7)	155.95	0.34(1)	.560
STAI	325.16(6)	348.75	324.75(7)	352.28	0.41(1)	.522
DERS	406.84(6)	431.70	406.83(7)	435.84	0.01(1)	.920
POMS	465.20(6)	490.06	462.29(7)	491.29	2.91(1)	.088
KSS	202.99(6)	227.84	202.82(7)	231.82	0.17(1)	.680
N1	1328.21(26)	1480.81	1111.58(102)	1710.25	216.63(76)	1.92e-15
P3	1666.25(26)	1818.85	1521.27(102)	2119.94	143.35(298)	3.22e-6
RT	3604.20(26)	3758.50	3213.14(102)	3818.50	393.43(76)	6.44e-44
ACC	1899.64(26)	2053.94	1459.82(102)	2065.72	439.82(76)	1.25e-52

Demographic and Expectancy

Table 2 contains descriptive statistics for study demographic and expectancy measures. Recruitment was predominantly female (female=22, male=11). The imbalance of males was small and non-significant, according to Chi-Square analysis (Relaxation=25%, MM=38%), $\chi2(1)=0.58$, $p=.444$, $V=0.13$. Levene's test showed violation of distribution for Age between groups, $F(1,30)=12.61$, $p=.001$. Further scrutiny found no significant difference of age between groups (MM=22.14, $SD=3.45$, Relaxation=22.06, $SD=1.73$), U=121, $p=.809$, $r=-0.05$.

Negligible and non-significant between-groups differences were found for FFMQ mindfulness, $t(30)=-1.55$, $p=.133$, CI 95% [-9.00, 1.25], $g=0.05$, and K10

scores, *t*(29)=-0.49, *p*=.625, CI 95% [-3.92, 2.40], *g*= 0.17. Between-group differences were small and non-significant for raw WTAR, *t*(30)=0.22, *p*=.826, CI 95% [-3.07, 3.82], *g*=0.08, and AUDIT scores, *t*(30)=-0.83 *p*=.415, CI 95% [-3.06, 1.00], *g*=0.29.

There was a moderate, significant difference in Mini-IPIP Extraversion scores, *t*(30)=-2.26, *p*=.031, CI 95% [-5.24, -0.26], *g*=0.76, indicating lower Extraversion scores in the control group. There were no significant differences between groups on other Mini-IPIP subscales.

Mixed analysis (see Table 1) of the KSS found a small non-significant main effect of Group, *F*(1,32)=1.23, *p*=.275, *g*=0.32, and Time, *F*(1,31)=<0.01, *p*=.578, *g*=0.02. Mean sleepiness did not significantly vary between groups (MM=3.45, *SD*=1.18, Relaxation=3.88, *SD*=1.41), or sessions (Pre=3.66, *SD*=1.29, Post=3.68, *SD*=1.35).

Independent t-tests found a moderate, non-significant, difference in expectancy for intervention to improve Attention, *t*(27)=1.75, *p*=.091, CI 95% [-0.13, 1.67], *g*=0.63, with controls holding greater expectancy. Small, non-significant differences were found for emotional wellbeing, *t*(27)=1.75, *p*=.193, CI 95% [-0.13, 1.70], *g*=0.36, and ability to complete computer tasks, *t*(27)=0.51, *p*=.613, CI 95% [-1.05, 1.74], *g*= 0.15. Groups did not significantly vary, with small effect, by the mean number minutes spent training with devices (Relaxation=146.88, *SD*=55.96, Meditation=127.86, *SD*=28.67), *F*(1, 28), 1.31, *p*= .262, *g*= 0.41. This was the same, with a moderate effect, for mean days spent training (Relaxation= 6.75, *SD*= 0.45., Meditation= 6.36, *SD*= 0.75), *F*(1, 28)=3.16, *p*=.086, *g*= 0.62.

Table 2.

Mean, SD and confidence intervals for demographic and expectancy measures.

	Relaxation				Meditation			
			95% CI				95% CI	
Measure	M	(SD)	Lower	Upper	M	(SD)	Lower	Upper
Age	22.06	(1.73)	21.14	22.99	22.31	(3.30)	20.55	24.07
WTAR[a]	41.81	(5.43)	38.92	44.70	41.53	(4.12)	39.25	43.82
K10	14.44	(4.23)	12.18	16.69	15.20	(4.38)	12.78	17.63
AUDIT	3.50	(2.56)	2.14	4.86	4.13	(3.00)	2.47	5.79
FFMQ	47.13	(8.16)	42.78	51.48	50.93	(6.03)	47.59	54.27
KSS								
Pre	3.94	(1.44)	3.19	4.70	3.38	(1.09)	2.80	3.95
Post	3.81	(1.42)	3.05	4.57	3.53	(1.30)	2.81	4.25
Expectancy								
Attention	7.20	(0.94)	6.68	7.72	6.54	(1.40)	5.70	7.38
Comp. Tasks	6.13	(1.77)	5.15	7.11	5.85	(1.95)	4.67	7.03
E.Wellbeing	7.40	(1.24)	6.71	8.09	6.85	(1.68)	5.83	7.86
Mini-IPIP								
Extra.	10.81	(3.16)	9.21	12.42	13.56	(3.83)	11.52	15.60
Agreeableness	16.38	(2.75)	14.91	17.84	16.81	(2.79)	15.33	18.30
Conscient.	13.63	(3.70)	11.65	15.60	14.50	(3.78)	12.49	16.51
Neuroticism	10.75	(3.22)	9.04	12.46	11.06	(3.26)	9.33	12.80
Imagination	13.88	(2.96)	12.30	15.45	15.19	(3.27)	13.45	16.93

Note. 95% CI = confidence interval, E.Wellbeing = Emotional Wellbeing, Conscient. = Conscientiousness, Comp. Tasks = Computer Tasks. [a]Scores reflect raw correct responses, hence may not be used to infer IQ.

Questionnaires

Table 3 contains cell means, *SD*s and 95% confidence interval statistics for repeated measure questionnaires. All analyses were run through mixed models (see Table 1). Aside from participant factors, measurement error meant final STAI data was further unbalanced between relaxation (n_{pre}=12, n_{post}=15) and MM (n_{pre}=11,

n_{post}=13). Boxplot observation showed extreme outliers in the relaxation group for the SDERS (n_{pre}=1, n_{post}=1) and POMS (n_{pre}=2, n_{post}=1). Mixed analyses were repeated with these points excluded, however no significant impact on main effects was observed. Data was retained.

Table 3.

Cell means, SD and 95% confidence intervals for SDERS, MAAS, CAMS, STAI and POMS by Time and Group.

		Relaxation			Meditation		
			95% CI			95% CI	
Scale	Time	*M* (*SD*)	Lower	Upper	*M* (*SD*)	Lower	Upper
SDERS	Pre	35.91 (7.97)	30.85	40.98	36.72 (5.97)	32.72	40.74
	Post	34.93 (7.75)	30.64	39.23	32.92 (6.95)	28.73	37.12
MAAS	Pre	3.94 (0.97)	3.33	4.56	3.85 (0.62)	3.44	4.27
	Post	3.83 (0.92)	3.32	4.34	3.70 (0.71)	3.27	4.13
CAMS	Pre	30.17 (4.80)	27.12	33.22	30.46 (5.26)	26.92	33.99
	Post	30.80 (4.31)	28.41	33.19	33.08 (3.45)	30.99	35.16
STAI	Pre	31.33 (8.27)	26.08	36.59	32.45 (7.76)	27.23	37.67
	Post	34.20 (7.88)	29.83	38.60	32.84 (5.90)	29.28	36.41
POMS	Pre	20.58 (14.13)	11.61	29.56	19.18 (6.65)	14.72	23.65
	Post	24.20 (16.94)	14.82	33.58	17.77 (7.14)	13.45	22.09

Note. 95% CI = confidence interval.

A significant, but small, main effect of time was found for SDERS scores, $F(1,30)=4.73$, $p=.037$, $g=0.36$, showing improvements to mean participant emotional regulation scores after a week (Pre =36.69, *SD*=6.89, Post=34.13, *SD*=6.98). Any effect of group on scores was small and non-significant, $F(1,31)=0.19$, $p=.668$, $g=0.15$. There was no significant time x group interaction.

Analyses found a small, non-significant main effect of time on CAMS rated mindfulness, $F(1,31)=3.47$, $p=.072$, $g=0.29$. This was also true for the main effect of group, $F(1,32)=0.84$, $p=.365$, $g=0.28$. There was no significant time x group interaction. There was a small, non-significant main effect of time, $F(1,31)=0.19$,

p=.670, g=0.05, and group, F(1,32)=0.01, p=.924, g=0.03, on MAAS score. There was no significant time x group interaction. The main effect of time on STAI scores was small and non-significant, F(1,24)=2.58, p=.121, g=0.22, as was the main effect of group, F(1,28)=<0.01, p=.956, g=0.03. There was no significant time x group interaction. POMS analysis revealed a small non-significant effect of time, F(1,32)=0.34, p=.563, g=0.07, and group, F(1,32)=1.44, p=.240, g=0.39. There was no significant time x group interaction.

Reaction Time (ms)

Model information is in Table 1. Table 4 contains estimated means for interactions and pairwise comparisons. Table 5 contains cell descriptive statistics for RT (ms). Cue and congruency RT displayed in Figure 2 and Figure 3, respectively.

A small, significant effect of time, F(1,346)=97.29, p<.001, g=0.34, indicated faster mean RTs after training (see Table 4). The main effect of group was small and non-significant, F(1,32)=0.05, p=.82, g=0.05. There was no significant time x group interaction.

There was a significant main effect of cue F(2, 346)=202, p<.001, with significant and moderately faster mean RTs for spatial cue, relative to central cue, p<.001, g=0.68, and central relative to no cue, with small effect, p<.001, g=0.23. The congruency main effect was large and significant, F(1,346)=1070, p<.001, g=1.37, showing faster RTs for congruent relative to incongruent flankers (see Table 4, Figure 2).

The hypothesised group x time x cue interaction was non-significant, F(2,346)=0.25, p=.780. Pairwise analyses showed significantly higher spatial cues, relative to central cues, at pre- and post-training for the MM group (p_{Pre}=.014, g_{Pre}=0.58, p_{Post}<.001, g_{Post}=0.52), these effects were also found, with small effects, in

the control group (p_{Pre}=.014, g_{Pre}=0.59, p_{Post}<.001, g_{Post}=0.29). There were no significant between-group differences at pre- or post-training for central (p_{Pre}=.835, g_{Pre}=0.08, p_{Post}=.662, g_{Post}= 0.10), or spatial (p_{Pre}=.725, g_{Pre}=0.10, p_{Post}=.929, g_{Post}=0.02) cues.

The hypothesised group x time x congruency interaction was non-significant $F(1, 346)$=<0.01, p=.944. Pairwise analyses showed a large, significant differences between incongruent and congruent flankers for MM at pre- and post-training (p_{Pre}<.001, g_{Pre}=1.21, p_{Post}<.001, g_{Post}=1.17). These differences were found large effect for the relaxation group (p_{Pre}<.001, g_{Pre}= 1.49, p_{Post}<.001, g_{Post}= 1.52).

Table 4.

Estimated means, SD, 95% confidence intervals, and pairwise comparisons for reaction time (ms).

		Cell Value					Contrast Estimates[a]		
				95 % CI				95% CI	
Factor	Value	M	(SD)	Lower	Upper	Pair	$M_{Diff.}$	Lower	Upper
Group									
1	Relaxation	492	(67.36)	482	501	--[b]	--	--	--
2	Meditation	489	(77.19)	478	500	2x1[b]	-3	-37	30
Time									
1	Pre	502	(75.01)	492	513	--[b]	--	--	--
2	Post	478	(67.32)	468	488	2x1**	-25	-30	-20
Cue									
1	No	515	(65.72)	504	527	2x1**	-16	10	22
2	Central	499	(72.57)	487	512	3x2**	-59	-66	-53
3	Spatial	456	(65.33)	445	468	3x1**	-43	-49	-37
Congruency									
1	Cong.	447	(56.00)	441	457	1x2**	-82	-87	-77
2	Incong.	531	(63.08)	522	540	--[b]	--	--	--

Note. CI refers to confidence interval, $M_{Diff.}$ refers to mean difference. [a]Based on mixed model estimates. [b]Inverse comparison reported. *Significant at .05. **Significant at<.001.

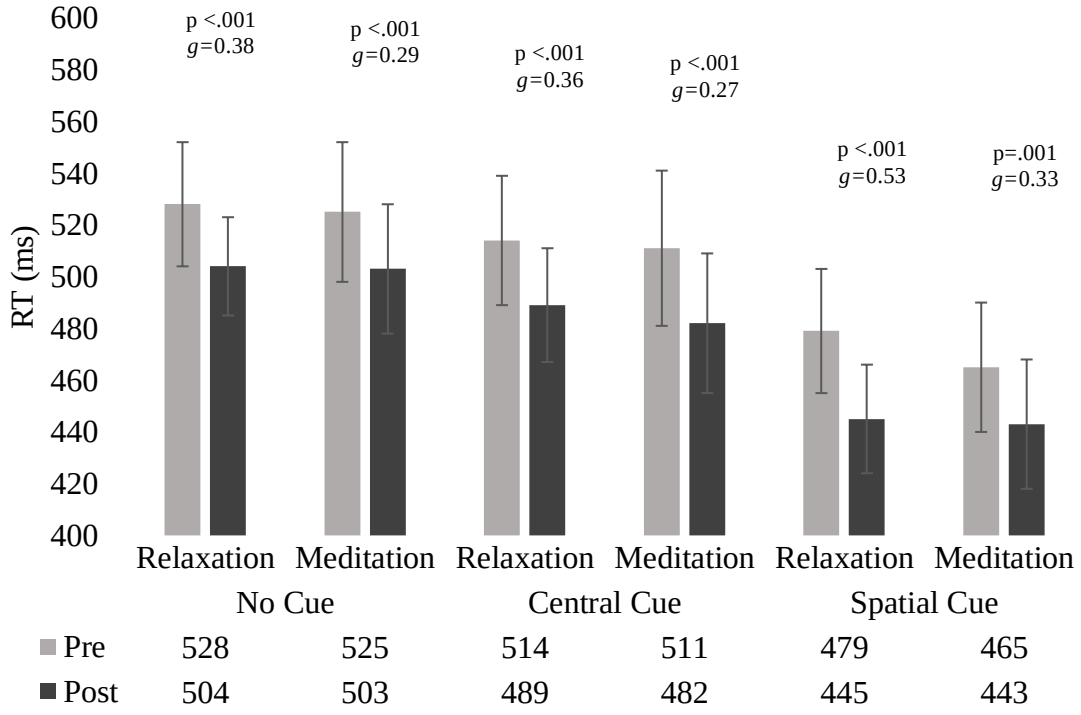

Figure 2. Mean RTs (ms), *g* and *p* for groups, by time and cue. Table contains condition means; error bars indicate 95% confidence intervals.

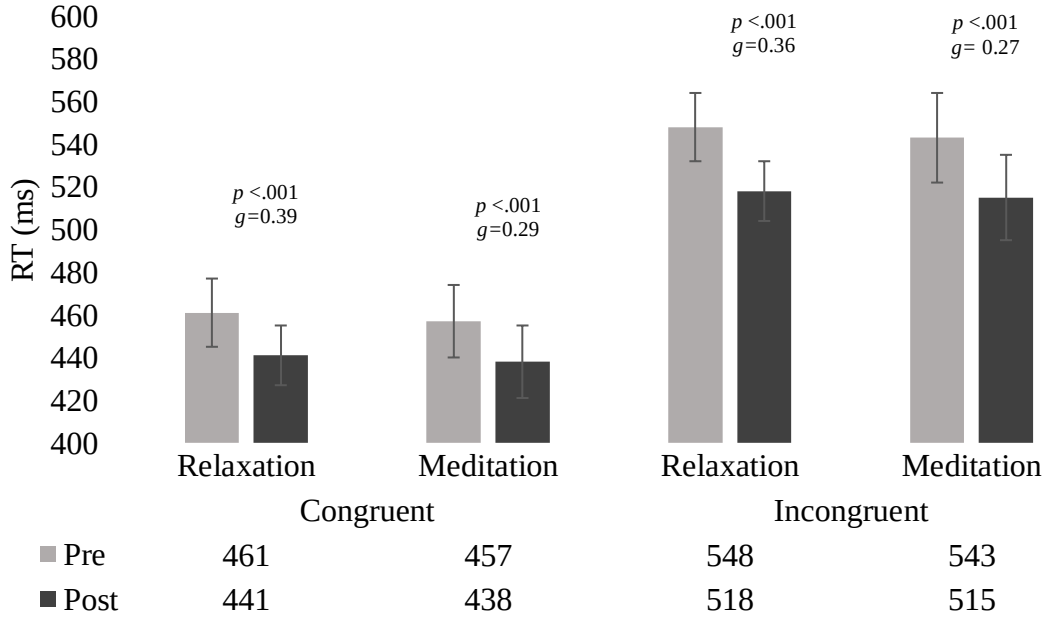

Figure 3. Mean RTs (ms), *g* and *p* for Groups, by time and congruency. Table contains condition means; error bars indicate 95% confidence intervals.

Table 5

RT (ms) cell means, SDs and 95% confidence intervals by time, congruency, cue and group.

			Relaxation			Meditation		
				95% CI			95% CI	
Time	Flanker	Cue	*M* (*SD*)	Lower	Upper	*M* (*SD*)	Lower	Upper
Pre	Congruent	No	488 (56.98)	457	518	486 (58.61)	455	517
		Central	464 (50.33)	437	491	459 (59.60)	428	491
		Spatial	431 (47.64)	405	456	427 (50.74)	400	454
	Incongruent	No	568 (45.05)	544	592	565 (71.35)	527	603
		Central	565 (45.42)	541	589	562 (69.03)	525	599
		Spatial	511 (57.44)	480	541	502 (65.65)	467	537
Post	Congruent	No	470 (50.92)	448	491	469 (50.92)	441	497
		Central	444 (40.27)	423	466	435 (53.65)	406	465
		Spatial	407 (40.81)	386	430	409 (55.03)	378	439
	Incongruent	No	538 (41.41)	517	561	537 (62.74)	503	572
		Central	534 (43.10)	511	557	528 (61.85)	494	563
		Spatial	481 (43.96)	458	505	478 (63.18)	443	513

Note. CI = confidence interval.

Accuracy (%)

Model information is in Table 1. Table 6 contains estimated descriptives and mixed pairwise comparisons for accuracy (% correct). Figure 4 depicts accuracy data (%) by group and time, cue and congruency. Table 7 contains cell descriptives by each condition. Extremely low accuracy data was excluded (<50%, *n*=1), distribution of scores is positively skewed. This otherwise reflects true outcomes, as lowest included accuracy was 79.69%.

Table 6.

Estimated means, SD, 95% confidence intervals and pairwise comparisons for accuracy (%).

		Cell Value					Contrast Estimates[a]		
				95 % CI				95% CI	
Factor	Value	M	(SD)	Lower	Upper	Pairs	$M_{Diff.}$	Lower	Upper
Group									
1	Relaxation	97.27	(3.74)	96.73	97.80	--[b]	--	--	--
2	Meditation	97.22	(4.07)	96.63	97.81	2x1[b]	-0.24	-1.44	1.39
Time									
1	Pre	97.22	(3.98)	96.65	97.78	--[b]	--	--	--
2	Post	97.27	(3.83)	96.72	97.82	2x1	0.12	-0.44	0.69
Cue									
1	No	97.04	(3.88)	96.35	97.72	2x1	-0.23	-0.92	0.45
2	Central	96.81	(3.99)	96.11	97.52	3x2[*]	1.07	0.38	1.76
3	Spatial	97.88	(3.78)	97.21	98.55	3x1[*]	0.83	0.15	1.52
Congruency									
1	Cong.	99.19	(1.52)	98.97	99.41	1x2[**]	3.89	3.33	4.45
2	Incong.	95.30	(4.54)	94.65	95.95	--[b]	--	--	--

Note. 95%CI = confidence interval, $M_{Diff.}$ = mean difference, Cong. = congruent, Incong. = incongruent. [a]Based on CS mixed model estimates. [b]Inverse comparison reported. [*]Significant at .05 level. [**]Significant at<.001 level.

Mixed model analyses revealed a small, non-significant main effect of Time, $F(1,348)=0.18$, $p=.672$, $g=0.01$, and Group, $F(1,31)=0.01$, $p=.973$, $g=0.01$, on accuracy, reflecting near parity of both factors.

Mixed analyses revealed a significant main effect of Cue $F(2,345)=5.16$, $p=.006$. Pairwise comparisons showed small, significant improvement in accuracy between spatial and centre cues (orienting effect; $p=.002$, $g=0.26$) and for spatial relative to no cue trials ($p=.018$, $g=0.21$). There was a non-significant difference between no and centre cue trials (alerting effect; $p=.505$, $g=0.06$). A large main congruency effect, $F(1, 345)=186.11$, $p<.001$, $g=1.12$, showed significantly more accurate responses for congruent, relative to incongruent flankers. There were no significant interactions.

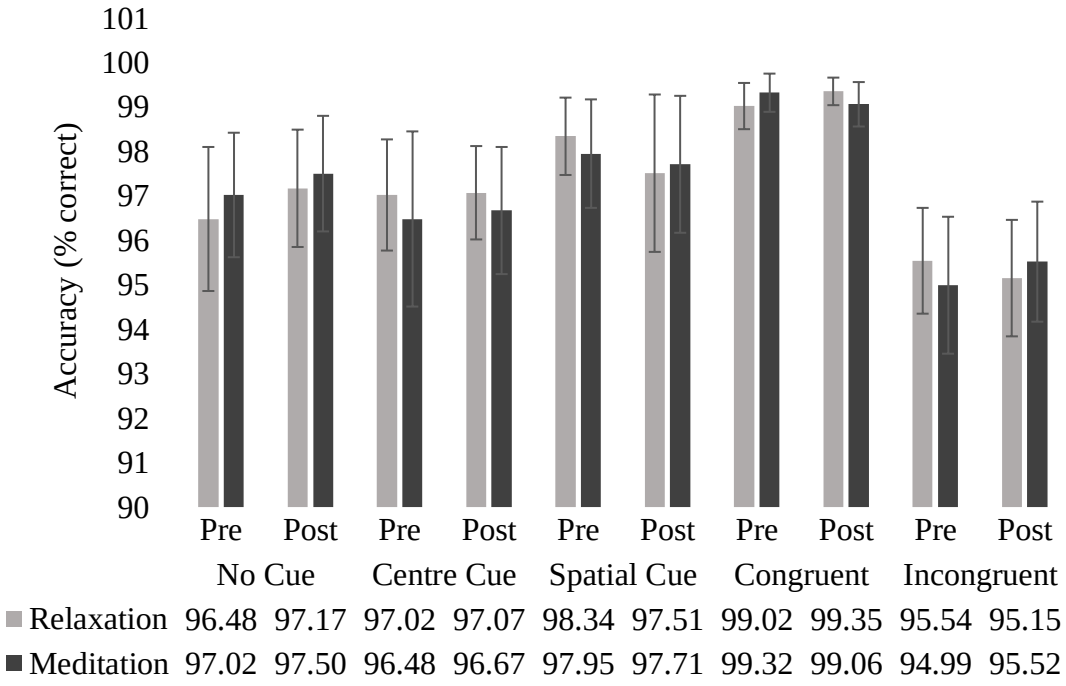

Figure 4. Overall task accuracy (% correct) by group and time. Error bars represent 95% confidence intervals.

Table 7.

Raw Accuracy (% correct) cell descriptive statistics, by time, congruency, cue and group.

			Relaxation			Meditation		
				95% CI (Mean)			95% CI (Mean)	
Time	Flanker	Cue	*M* (*SD*)	Lower	Upper	*M* (*SD*)	Lower	Upper
Pre	Congruent	No	98.83 (2.17)	97.67	99.99	99.41 (0.97)	98.90	99.93
		Central	99.12 (1.61)	98.26	99.98	99.22 (1.98)	98.17	100.27
		Spatial	99.12 (1.71)	98.21	100.03	99.32 (1.40)	98.57	100.60
	Incongruent	No	94.14 (5.06)	91.45	96.83	94.63 (4.27)	92.36	96.90
		Central	94.92 (3.59)	93.01	96.83	93.75 (6.48)	90.30	97.20
		Spatial	97.56 (2.80)	96.07	99.05	96.58 (4.20)	94.34	98.82
Post	Congruent	No	99.51 (0.94)	99.01	100.01	99.06 (1.65)	98.15	99.98
		Central	98.93 (1.36)	98.20	99.65	98.75 (1.98)	97.66	99.85
		Spatial	99.61 (0.70)	99.24	99.98	99.38 (1.29)	98.66	100.09
	Incongruent	No	94.82 (3.90)	92.75	96.90	95.94 (4.13)	93.65	98.22
		Central	95.22 (2.88)	93.68	94.53	94.58 (4.13)	92.30	96.87
		Spatial	95.41 (6.31)	92.05	98.78	96.04 (5.25)	93.14	98.95

Note. 95% CI = confidence interval.

Oz N1 Amplitude (μV)

Mixed model information is in Table 1. Pairwise means, *SD*s, 95% confidence intervals and model estimates for N1 (μV) can be found in Table 8, cell descriptives in Table 9. Waveform averages, with boxplots are displayed in Figures 5 and 6. Boxplot observation identified an extreme outlier in the Post-Relaxation, Central Cue, Congruent condition. Additional analyses were run with the trial, and then the participant, removed from the pool. This did not significantly influence main effects, data was retained.

Table 8.

Estimated means, SD, 95% confidence intervals, and pairwise comparisons for N1 amplitude (μV) at Oz.

		Cell Value					Contrast Estimates[a]		
				95 % CI				95% CI	
Factor	Value	M	(SD)	Lower	Upper	Pairs	$M_{Diff.}$	Lower	Upper
Group									
1	Relaxation	-1.84	(2.63)	-2.23	-1.45	--[b]	--	--	--
2	Meditation	-1.17	(2.99)	-1.62	-0.72	2x1	-0.62	-1.03	2.27
Time									
1	Pre	-1.66	(2.82)	-2.08	-1.23	--[b]	--	--	--
2	Post	-1.37	(2.84)	-1.79	-0.95	2x1	0.27	-0.03	0.56
Cue									
1	No	-0.75	(2.35)	-1.18	-0.32	2x1	-0.28	-0.63	0.07
2	Central	-1.01	(2.69)	-1.50	-0.52	3x2[**]	-1.74	-2.09	-1.39
3	Spatial	-2.77	(2.99)	-3.31	-2.22	3x1[**]	-2.02	-2.37	-1.67
Congruency									
1	Cong.	-1.42	(2.86)	-1.32	-1.00	1x2	0.17	-0.12	0.45
2	Incong.	-1.60	(2.80)	-2.01	-1.18	--[b]	--	--	--

Note. 95% CI = confidence interval, $M_{Diff.}$ refers to mean difference. [a]Based on CS mixed model estimates. [b]Inverse comparison reported. [**]Significant at<.001 level.

Analyses found a small, non-significant main effect of Group and of Time on N1 amplitude, $F(1,31)=0.59$, $p=.450$, $g=0.23$, revealing a negligibly raised N1 amplitudes for the MM group compared to controls, and from pre- to post-training, $F(1,324)=3.23$, $p=.073$, $g=0.01$.

There was a significant main effect of cue, $F(2,323)=75.96$, $p<.001$. Pairwise analyses found a moderate, significant difference between centre and spatial cues for N1 magnitude, $p<.001$, $g=0.63$. There was a small and non-significant difference between incongruent and congruent flankers, $F(1,323)=1.36$, $p=.245$, $g=0.07$, which showed negligibly elevated congruent N1 amplitude.

The hypothesised Time x Cue x Group interaction was non-significant, $F(2, 323)=0.57$, $p=.878$. Planned pairwise analyses supported our secondary hypothesis of decreased N1 magnitude Post-MM. There was a small and significant reduction in mean N1 amplitude for central cue between pre and post measurement (Pre= -1.19, *SD* =3.01, Post=-0.26, SD=2.78), $p=.010$, $g=0.30$. This was also found following mean target N1 spatial cues between pre-post (pre=-2.77, *SD*=2.76, post=-1.98, *SD*=3.16), $p=.026$, $g=0.25$). There was a moderate and significant difference between central and spatial cues, showing decreased N1 amplitude at both pre and post-MM ($p_{Pre}<.001$, $g_{Pre}=0.52$, $p_{Post}<.001$, $g_{Post}=0.55$). However, mean differences between groups were non-significant at pre or Post-training for central ($p_{Pre}=.781$, $g_{Pre}=0.13$, $p_{Post}=.382$, $g_{Post}=0.28$), and spatial cues ($p_{Pre}=.954$, $g_{Pre}=0.06$, $p_{Post}=.135$, $g_{Post}=0.41$).

Table 9.

N1 Amplitude (μV) cell descriptives by time, group, cue and congruency.

			Relaxation			Meditation		
				95% CI			95% CI	
Time	Flanker	Cue	*M* (*SD*)	Lower	Upper	*M* (*SD*)	Lower	Upper
Pre	Congruent	No	-0.41 (2.51)	-1.87	-1.04	-0.77 (2.49)	-2.15	0.61
		Central	-1.61 (2.52)	-3.07	-0.16	-1.27 (2.93)	-2.90	0.35
		Spatial	-3.04 (3.47)	-5.04	-1.04	-2.75 (2.83)	-4.32	-1.19
	Incongruent	No	-1.38 (1.64)	-2.32	-0.44	-0.42 (3.02)	-2.09	1.26
		Central	-1.51 (2.71)	-3.07	0.05	-1.10 (3.19)	-2.86	0.67
		Spatial	-2.86 (2.42)	-4.26	-1.47	-2.78 (2.80)	-4.33	-1.23
Post	Congruent	No	-1.15 (1.41)	-1.91	-0.40	0.32 (2.73)	-1.89	1.26
		Central	-0.80 (2.43)	-2.09	0.50	-0.32 (2.73)	-1.89	1.26
		Spatial	-2.97 (3.28)	-4.71	-1.22	-1.85 (3.30)	-3.76	0.06
	Incongruent	No	-1.42 (1.79)	-2.38	-0.47	-0.30 (2.79)	-1.91	1.31
		Central	-1.25 (2.36)	-2.51	0.00	-0.21 (2.94)	-1.91	1.48
		Spatial	-3.62 (2.93)	-5.18	-2.06	-2.10 (3.14)	-3.91	-0.29

Note. CI = confidence interval.

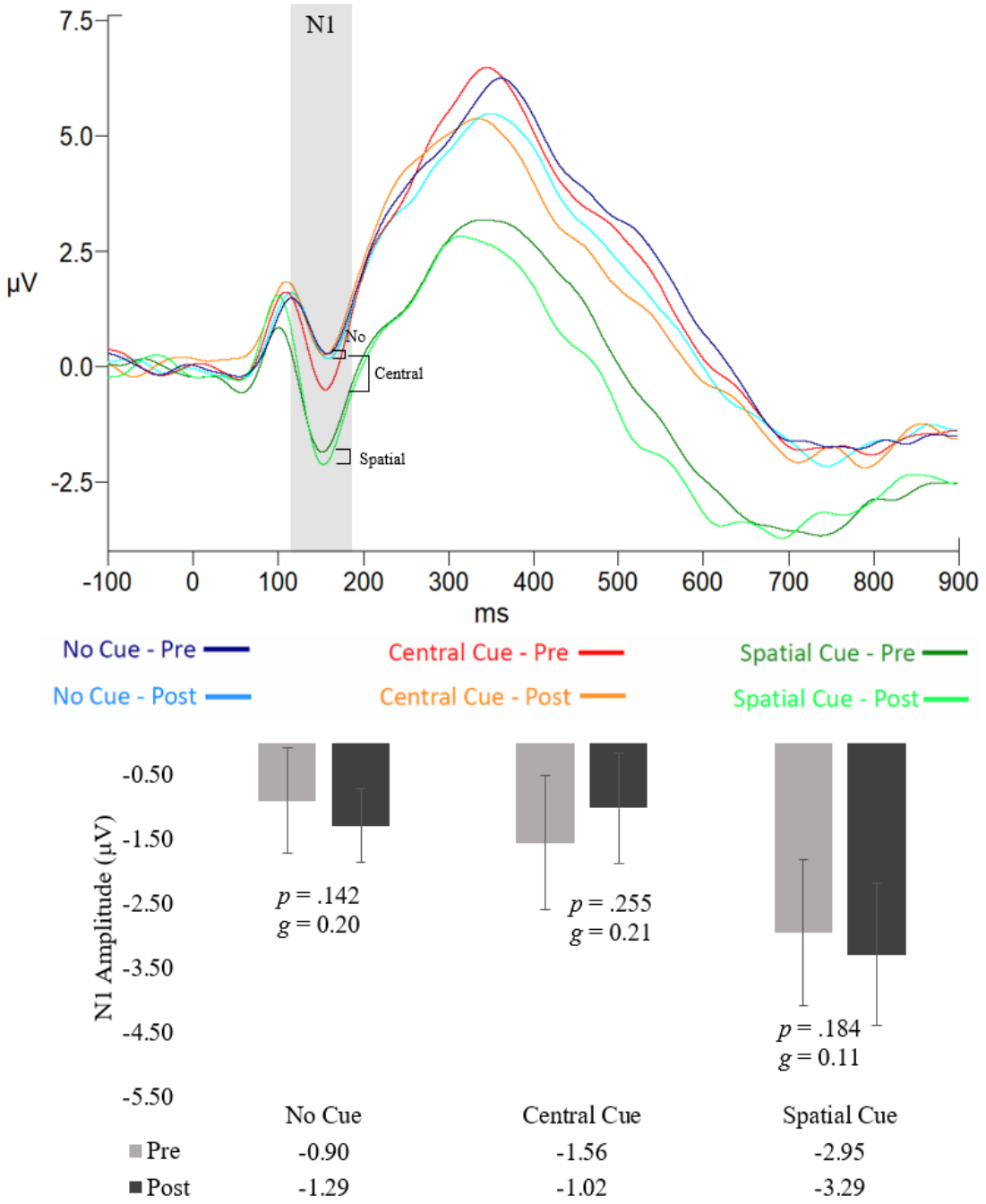

Figure 5. Relaxation N1 grand mean waveforms (Oz), displayed by time and cue, averaged across congruency. Bar graph for amplitude (μV) cell means, and 95% confidence intervals (error bars). Relevant effects and significance are indicated.

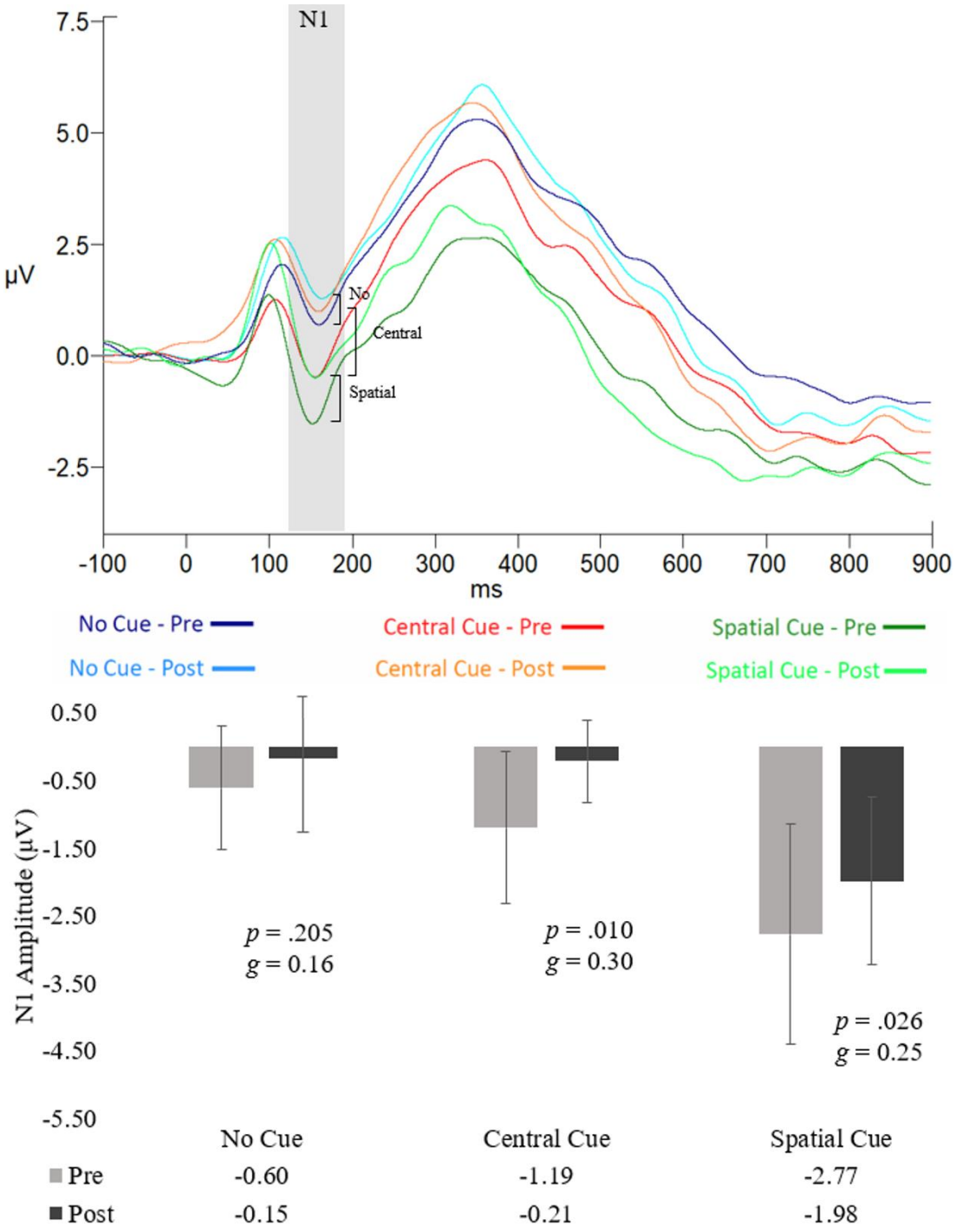

Figure 6. Meditation N1 grand mean waveforms (Oz), displayed by time and cue, averaged across congruency. Bar graph for amplitude (μV) cell means, and 95% confidence intervals (error bars).

P3 Amplitude at Fz (μV)

Model information is in Table 1. Estimated main means and pairwise interactions are in Table 10. Cell means and descriptives can be found in Table 11. Figure 7 (Relaxation) and 8 (Meditation) show grand averaged waveforms by congruency and time, graph displays conditions means, and 95% confidence intervals. Boxplot observation identified an extreme outlier in the post-relaxation congruent, centre cue condition. Additional analyses were run with the specific trial, and then the participant, excluded. Presence of the outlier did not significantly impact main effects. Data was retained.

Mixed model analyses revealed a moderate, significant main effect of group on P3 amplitude, $F(1,31)=6.53$, $p=.016$, $g=0.58$, indicating lower P3 amplitudes for the MM group when compared with controls. Analyses found a significant and small main effect of Time, $F(1, 327)=4.45$, $p=.036$, $g=0.10$, which reflected lower Post-training amplitudes compared to baseline.

A significant main effect of cue $F(2, 323)=46.48$, $p<.001$, was found. Pairwise comparisons showed no cue was moderately, and significantly lower than central cue ($p<.001$, $g=0.63$) A small, non-significant difference was found between central and spatial cue, $p=.153$, $g=0.13$. The difference between incongruent and congruent flankers was small and non-significant, $F(1,323)=0.02$, $p=.897$, $g=0.03$. Analyses also revealed an un-hypothesised, significant group x cue interaction, $F(2,323)=3.28$, $p=.039$ ($p_{Bonferroni=}.008$).

The hypothesised time x group x congruency interaction was non-significant, $F(2,322)=2.02$, $p=.156$. Planned comparisons showed the difference between incongruent and congruent flankers was negligible and non-significant at pre and post-MM ($p_{Pre}=.396$, $g_{Pre}=0.05$, $p_{Post}=.267$, $g_{Post}=0.15$). A moderate and significant

difference was found between baseline Incongruent means for groups, (Relaxation=7.56, *SD*=3.44, MM=4.98, *SD*=3.36), *p*=.012, *g*=0.74. However, there were small, and non-significant difference between group means for Post-training Incongruent trials (Relaxation=6.75, *SD*=3.44, MM=5.20, *SD*=3.57), *p*=.070, *g*=0.43.

Table 10.

Estimated means, SD, 95% confidence intervals, and pairwise comparisons for P3 at Fz (μV).

		Cell Value					Contrast Estimates[a]		
				95 % CI				95% CI	
Factor	Value	M	(SD)	Lower	Upper	Pair	M_{Diff}	Lower	Upper
Group									
1	Relaxation	7.13	(3.40)	6.63	7.63	--[b]	--	--	--
2	Meditation	5.06	(3.52)	4.53	5.58	2x1[*]	-2.15	-3.86	-0.43
Times									
1	Pre	6.31	(3.70)	5.75	6.86	--[b]	--	--	--
2	Post	5.93	(3.52)	5.41	6.44	2x1[*]	-0.52	-1.01	-0.04
Cue									
1	No	4.47	(3.67)	3.80	5.14	1x2[**]	-2.25	-2.83	-1.66
2	Central	6.72	(3.32)	6.11	7.32	2x3[ns]	-0.43	-1.01	0.16
3	Spatial	7.15	(3.26)	6.55	7.74	1x3[**]	-2.68	-3.26	-2.09
Congruency									
1	Cong.	6.10	(3.64)	5.56	6.64	1x2	-0.03	-0.51	0.45
2	Incong.	6.12	(3.58)	5.59	6.65	--[b]	--	--	--

Note. 95% CI = confidence interval, $M_{Diff.}$ refers to mean difference. [a]Based on CS mixed model estimates (see Table 1). [b]Inverse comparison reported. [*]Significant at .05 level. [**]Significant at<.001 level.

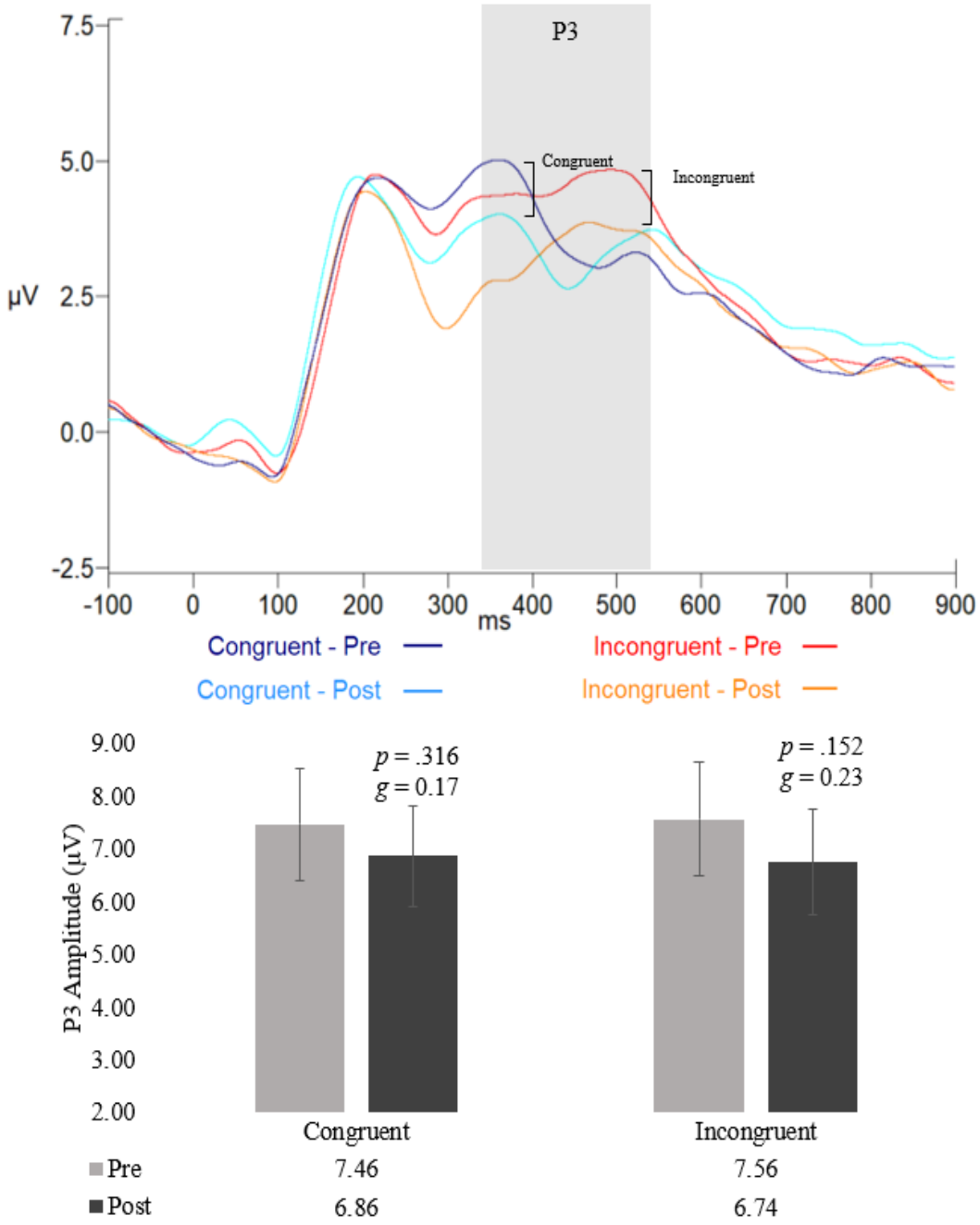

Figure 7. Relaxation P3 grand mean waveforms (Fz), displayed by time and cue, averaged across congruency. Bar graph for amplitude (μV) cell means, and 95% confidence intervals (error bars). Relevant effects and significance are indicated

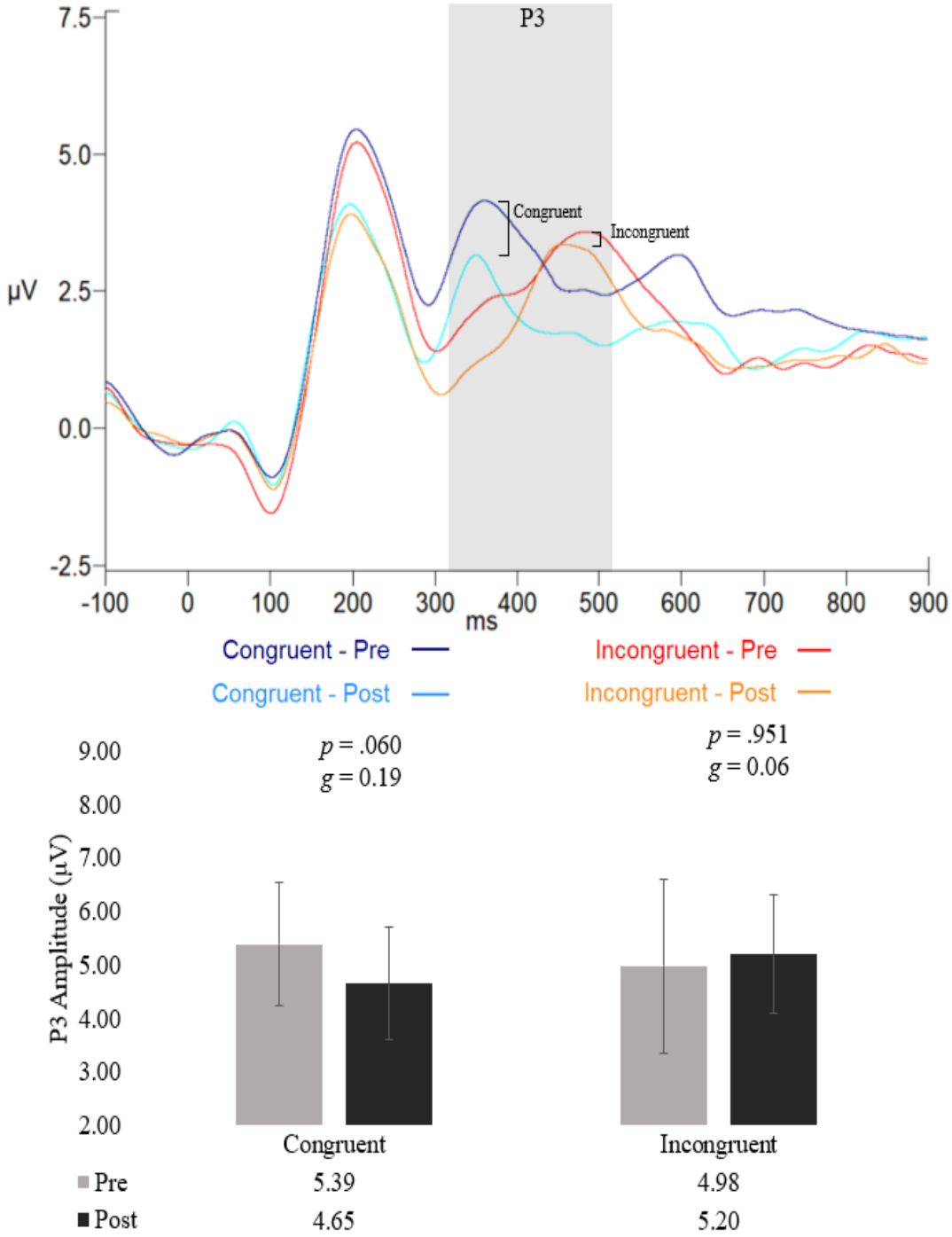

Figure 8. Meditation P3 grand mean waveforms (Fz), displayed by time and cue, averaged across congruency. Bar graph for amplitude (μV) cell means, and 95% confidence intervals (error bars). Relevant effects and significance are indicated.

Table 11.

Cell means, SDs and 95% confidence intervals for P3 (μV) by time, congruency, cue and group.

			Relaxation			Meditation		
				95% CI			95% CI	
Time	Flanker	Cue	*M* (*SD*)	Lower	Upper	*M* (*SD*)	Lower	Upper
Pre	Congruent	No	6.48 (3.28)	4.59	3.38	3.16 (4.08)	0.90	5.42
		Central	8.04 (3.84)	5.83	10.26	6.20 (2.53)	4.80	7.60
		Spatial	7.85 (3.29)	5.96	9.75	6.80 (3.93)	4.63	8.98
	Incongruent	No	6.40 (4.40)	3.86	8.94	2.80 (2.85)	1.27	4.32
		Central	7.87 (3.22)	6.01	9.73	5.22 (3.42)	3.63	7.42
		Spatial	3.40 (2.27)	7.09	9.71	6.61 (2.80)	5.06	8.16
Post	Congruent	No	5.93 (3.10)	4.28	7.58	2.87 (3.32)	0.96	4.79
		Central	3.49 (3.23)	5.67	9.11	5.55 (2.95)	3.85	7.26
		Spatial	7.26 (3.53)	5.38	9.14	5.51 (3.31)	3.60	7.43
	Incongruent	No	4.95 (3.38)	3.15	6.76	3.11 (2.90)	1.44	4.79
		Central	7.27 (3.41)	5.45	9.08	5.84 (3.43)	3.85	7.82
		Spatial	8.01 (2.94)	6.45	9.58	6.66 (3.54)	4.61	8.70

Note. 95% CI = confidence interval.

Discussion

This study sought to determine the efficacy of MM as an attentional intervention through quantifying human measures of electrophysiology (N1/P3 amplitudes) and behaviour (Accuracy and Reaction Time) elicited through the Attention Network Test. Our main hypothesis of decreased RTs for spatial cues, relative to central cues post-MM, relative to controls with associated N1 amplitude reduction was non-significant. Our hypothesis of decreased RTs for incongruent relative to congruent flankers post-MM, relative to controls, and associated P3 amplitude reduction was non-significant. Our secondary N1 hypothesis was supported, but not our P3 hypothesis, in that amplitudes would decrease given no significant improvement in RT. N1 amplitudes were reduced post-MM for spatial and central cues, although this was not significant when compared to controls. P3 amplitude differences for Congruent and Incongruent trials were non-significant between groups, with the MM group reflecting higher P3 for congruent, relative to incongruent, trials. Our manipulation checks, aside from SDERS, were non-significant after a week of training, despite equal adherence to device training between groups.

Secondary Outcomes

Our results showed elevated baseline levels of Mini-IPIP Extraversion scores in the MM group, relative to controls. Studies have associated Extraversion levels, albeit rated by FFMQ, with improved executive inhibition in the ANT (Matthews & Zeidner, 2012). The control group registered moderately higher levels of expected attentional improvement after receiving their device. While this potentially supports the efficacy of our active-control condition in guarding against technology-related placebo in the MM condition, it may also have unintentionally has a confounding

effect on the control group's attentional measures (Boot, Simons, Stothart, & Stutts, 2013). Groups were otherwise considered homogenous at baseline in terms of computer task and emotional regulation expectancy, intelligence, age, sex, interventional adherence, and sleepiness. This negates any confounding effects of these factors.

Groups reported perceived elevations in emotional regulation after training in the SDERS. This indicates successful manipulation of the MM intervention and active relaxation control condition. However, as state-based factors are found to regularly fluctuate (Kiken, Garland, Bluth, Palsson, & Gaylord, 2015), we must be tentative in our interpretation. Interventions were otherwise not found to manipulate state- or trait-based factors. While other studies have observed personality changes after short-term MM (Tang et al., 2007), these changes were observed after trainer-guided meditation in a school environment. While intervention adherence was tracked, we were unable to ensure that sessions were of a uniformed standard, or that participants were free from distractions.

We used mean scores to compare between-group differences of state- and trait-base dispositions. It must be noted that these measures were used only as manipulation checks, however, other studies have employed individual variance within groups (e.g., neuroticism; Norris et al., 2018) as a covariate factors when considering between-group comparisons. As we also lacked additional measures for growth-curve analyses, we are unable to confidently state that personality had no true influence on MM training outcomes.

Behavioural Findings

Reaction Time. As expected, we observed orienting and executive effects through the ANT, supporting efficacy of the test in eliciting network-specific

responses in accordance with the literature (Fan et al., 2009). We found lower RTs as cue informativeness rose; no cue>central cue>spatial cue. An overall improvement in group RT was observed after a week of training, but there were no significant differences between groups, or evidence of a significant group x time interaction. True to our hypothesis, there was a significant improvement in orienting post-MM training, relative to baseline. Specifically, our primary hypothesis was not supported as we observed non-significant and small differences for central and spatial cues between groups at Post-training. This suggests that, while orienting RT may have improved for the MM group, and we observed the hypothesised effect, the difference between relative cues for MM and Relaxation groups was non-significant. Accordingly, and relative to controls, MM did not significantly enhance Orienting RTs.

We observed significant improvements in RT for congruent, relative to incongruent trials, supporting an executive effect for both groups. This is also in accordance with the literature (Fan et al., 2009). Planned comparisons showed that this effect remained stable from Pre- to Post-training for MM (Pre-$M_{\text{Difference}}$=85ms, Post-$M_{\text{Difference}}$=77ms). Again, our specific hypothesis, that there would be an observed improvement from Pre-Post MM training in executive attention, relative to controls (Pre-$M_{\text{Difference}}$=86ms, Post-$M_{\text{Difference}}$= 77ms), was not supported. Although improved SDERS scores were reported for both groups, our design prevents us from inferring any true effects of training. It is possible that MM and Relaxation training, and increased executive attentional control through emotional regulation improvements (Chiodelli et al., 2018), were equally as effective at improving subjects' ability to curb reactivity to Incongruent flankers relative to Congruent flankers

It is tempting to conclude that Relaxation and Meditation are equally effective at improving RT, however, we are mindful of documented practice effects for the ANT, particularly for executive measures (Ishigami, 2011). Without a non-active control for comparison, we are unable to determine whether effects were due to equal efficacy of MM and Relaxation on performance. Accordingly, we tentatively conclude that practice effects underlie these findings.

Accuracy. Overall ANT response accuracy was high for both intervention and controls, in all conditions. This negates the influence of a speed-accuracy trade-off for faster Post-testing RTs, again reflecting potential practice effects as opposed to the efficacy of training conditions. Consistent with our RT findings, Accuracy improved relative to the informativeness of cue and congruency type, with spatial cue and congruent flankers yielding the greatest accuracy. Consistent with other MM studies, Accuracy did not differ between groups (Jha et al., 2007).

Electrophysiological Findings

N1 Amplitude (μV). As expected, we found significantly greater N1 amplitudes on spatial cue relative to central cue trials overall, this aligned with our main findings for RT. This difference was found in both groups at pre- and post-training, in order of greatest magnitude; spatial cue>central cue>no cue. However, as there was no difference between N1 magnitudes for groups at Post-training, we cannot retain our primary hypothesis; that elevated N1 amplitudes would coincide with faster Post-MM RTs relative to controls.

Further analyses of the N1 supported our secondary hypothesis that, given stability of RT between groups over time, N1 magnitudes would significantly decrease for the MM group at Post-training relative to baseline measures. Although this magnitude change would not be significant when compared to control group

measures, we did observe a different pattern of change for MM. From Pre to Post-training, the Relaxation group expressed increased N1 magnitudes during No and Spatial Cues, with only decreased magnitudes shown in Central Cue conditions. Conversely, compared with baseline measures, the ANT elicited lowered N1 magnitudes for all Cue types at Post-training for the MM group. The literature suggests that N1 amplitudes increase in line with the informativeness of Cues (Neuhaus et al., 2010). Given that, as ERPs reflect cellular processes that underlie cognition, and that lower N1 was observed for relatively unchanged RTs over time for MM compared to controls, we posit that the observed lower magnitude N1 for the MM group reflects either a) less cognitive 'effort' (i.e., lower levels of firing to achieve the same outcome) or b) that the MM group had greater dispersion of processes, causing a reduction in localised signalling, causing lower peak amplitudes through engagement of a wider network resource during Orienting. Additionally, as ERPs are not controlled by conscious processes, the effect of practice is not a consideration when interpreting these results, as it is for RT and/or accuracy.

P3 amplitude (μV). Our primary hypothesis was that MM group P3 amplitudes would increase in tandem with an observed RT improvement for executive attention, relative to controls. We found large executive RT effects in the MM group, however the difference between congruent and incongruent RTs were not significant compared to those of controls. The magnitude of between-group differences for congruent trials increased from baseline to post-training, with the MM group showing a greater reduction in P3 amplitudes. Incongruent amplitudes were significantly lower for the MM group at baseline, relative to controls, the difference between groups had become non-significant at post-training. Despite large effects observed at pre- and post-training for RT, the MM group expressed almost

unchanged P3 amplitudes for incongruent trials from pre- to post-measurement. This contrasted falling, albeit non-significant, P3 amplitudes for incongruent trials elicited between pre- and post-training. Accordingly, we rejected our secondary hypothesis.

While the MM group had shown a significant decrease in RT between sessions, this change was also mirrored by stable P3 amplitudes. If MM training was to improve network efficiency, the change in RT should have also coincided with less cellular 'effort' precluding the MM group's reactions to target stimuli. The group still had lower overall P3 amplitude, however, their P3 amplitudes began at a lower level than that of the Relaxation group. Furthermore, the Relaxation group's P3 amplitude had dropped further than that of the MM group at post training.

The P3 findings are surprising, given the general consensus regarding what the component represents; interference caused by conflicting task demands (Neuhaus et al., 2010). We found no significant changes in P3 magnitudes relating to congruency, however, incongruent P3 magnitudes were smaller on average for the MM group. This may suggest that early MM training is effective at improving attentional, but not executive network efficiency. P3 amplitudes for the MM group were smaller on average, for incongruent trials, when compared to the relaxation group. Due to the later nature of the component, compared to others such as the N1, its interpretation may be muddied by additional cognitive processes, and may stand to reflect multiple mechanisms related to inhibition. Galvao-Carmona et al. (2014), argued that smaller incongruent component could represent simultaneous processes, such as target evaluation, and assessment of relevancy or even a spread of resources during more challenging tasks – participants may have engaged a more disperse network to address the greater difficulty of Incongruent flankers. We cannot rest on these conclusions, as our data only drew from a single electrode. In saying that, we

agree with Galvao-Carmona et al (2014) in that further study into the true nature of the P3 component, perhaps through multiple combinations of electrodes, or multi-network coherence, is warranted.

Study Limitations and Future Directions

Time and Participants. Due to time constraints (see Appendix D), we were unable to recruit the desired number of participants. This had several implications for our study, and our model (discussed below). One of the main implications of this was our inability to extend training beyond a single week. While studies have found significant changes in mindfulness measures and attention after a week's training (Tang et al., 2007), these changes are not commonly found in the literature. Accordingly, our hypothesised results expected greater outcomes than is generally consistent with the literature. Constraints also meant that we were unable to balance our participant pool in terms of sex. By now, it is well-recognised, yet contentious, that structural differences exist between the male and female brain studies (Xin, Zhang, Tang, & Yang, 2019). These are likely to have significant implications for neurocognitive research. In reference to the current study, there is a wealth of literature to support the differential effects of mindfulness and/or meditation practice between men and women (Rojiani, Santoyo, Rahrig, Roth, & Britton, 2017), in that women receive greater benefit from mindfulness-based training when compared to men. Although analyses showed that our study was balanced in terms of male distribution between groups, lower group numbers meant any sex differences between scores may have muddied the interpretation of dispositional changes between groups. It is recommended that future studies either a) gain participant numbers>40, or, unless comparing differential sex effects, b) consider the studying the impact of MM on isolated sex-specific groups. As studies emerge, it becomes

more apparent that failing to adhere to the latter is ignoring inherent individual differences within groups.

Participant Expectancy. Our study was designed to target any confounding technology-related expectancy bias through to inclusion of an active control group. Boot, Simons, Stothart, and Stutts (2013) argue that this effort may still have been insufficient in negating such an effect, with controls reporting greater expectancy measures relating to attention. Accordingly, we did not to ensure balanced expectancy between groups (Boot et al., 2013). While an active control may have attenuated re-test effects and regression to the mean, expectancy self-report measures suggest it may also have unintentionally added outcome-expectancy bias relating to our primary measures. Again, we are unable to quantify any influence this may have had, relative to a on outcome measures without the presence of a non-active control group. Without the presence of a waitlist, or true control group, our study design may ultimately have been flawed. We are hence unable to imply any causation regarding MM efficacy. We recommend that future studies balance this expectancy.

State-Based Measures. There is indication that repeated meditation practice may influence state-based mindfulness measures, and subsequently affect change in trait-type mindfulness (Kiken et al., 2015), as measured by scales such as the MAAS. Aside from a main effect of time on emotional regulation outcomes, our study found little other dispositional impact of MM practice between onset and completion of training. As state-based measures are prone to regular fluctuation, future studies may consider daily, or repeated, ratings of perceived mindfulness between experimental sessions. This would allow researchers to account for any extraneous stressors (i.e, University assignments/exams) that may arise on either day of measurement or increase as time progresses. Multiple (>2) measures would also allow growth-

modelling related to state- and trait-based factors. Referring to comments from Kiken et al. (2015), it may also be appropriate to consider other outcomes, such perceived cognitive reappraisal in assessing any impact of MM training on personality factors. Importantly, researchers may opt to partition variance of state measures between individuals in conjunction with pooled total group ratings.

Mixed Models Analysis. Participant numbers were a significant limitation of our study, particularly with our selection of Mixed models. We successfully used mixed models to maximise data retention, which accounted for anticipated measurement error, and participant attrition. Compared to Restricted Maximum Likelihood, the use of Maximum Likelihood increased our study power and allowed us to compare models between outcomes, however the strength of its flexibility may also have been a weakness. While outliers were not observed to significantly impact our interactions, our smaller pool may have caused further-reaching, unanalysed, implications for pairwise comparisons. This was a likely downfall in our selection. Furthermore, considering the potential precision of mixed models, its use as a robust repeated measures ANOVA may have opened up potential for exaggerated outcomes. Mixed models are intended to be a precision instrument, and correct fitting of intercepts and/or slops through a step-by-step basis prevents over- or under-estimation of significance. Future studies may choose to select covariant factors to achieve a more nuanced approach, as demonstrated in Galla (2016). While our pre-post design prevented growth-curve analyses, it did not limit us in considering nuanced partitioning of variance. The modelling of time-varied, participant-nested intercepts for factors known to significantly vary between individuals (i.e., state-based mindfulness; Kiken et al., 2015), may have delivered more meaningful results. However, low sample size would likely have rendered any such correlations

spurious. Due to the nature and varied retention of our data, a mixed model is still preferred over a standard repeated measures ANOVA.

Analyses of ERP peaks. Our study was comprehensive in considering additional electrophysiological measures of attention, in conjunction with behavioural outcomes. However, in conclusion, we refer to a well-cited and brief ERP guide set by Luck (2005). There are potentially significant limitations waveform peak analyses when investigating complex and disperse neurocognitive processes. Considering the averaged magnitude and latency of peaks to be a true representation of latent components can lead to erroneous interpretations through a) the flattening of true component amplitudes, and b) spreading observations over a longer latency period than was truly observed. Referring to our comments regarding state-based measures, the use of group-averaged observations is likely denying the importance of individual variance relating to interventions. However, this is common practice (Fan et al., 2009; Neuhaus et al., 2010), and the foundation of studies such as our own. The assessment of averaged peaks may be inherently flawed; a paradigm shift may benefit the field. Future studies must first address problems relating to group size, and power, before approaching data with the same consideration for individual neurocognitive variance within humans as is accorded by ecologists to the genetic variance in the study of other animals (Wilson et al., 2010).

Conclusion

This study offered much to the existing body of research into MM training and attention. Importantly, it addressed a gap in the literature by providing much-needed electrophysiological data measured by the ANT following short-term neurofeedback-assisted MM training, relative to an active control group. Although no significant improvement on behavioural performance, or related N1 or P3

amplitudes, were found relative to controls, we did find some evidence of MM delivering greater early selective attentional efficiency through reduced N1 magnitudes. This may have come through improved improved network efficiency.

We refer to van Dam et al. (2018), in highlighting the significance of this point, however trivial in specificity it may seem. While the scientific community struggles to gain consensus of what constitutes MM, the medical and professional worlds have long since integrated it into practice. This is a problem because a) if there are true benefits to MM, the discovery of these is imperative in offering non-pharmaceutical interventions for those with cognitive dysfunction, and b) if there are no true benefits to MM, then potential billions may be wasted on its employ. We offer findings relating to healthy, young adults accompanied by a comprehensive list of dispositional questionnaire outcomes. Given the scarcity of such studies, our own may be used to support further research into this field. Furthermore, we provide a case for the use of mixed models in such research. This too is important, as flexible and exact methods of analyses will be required if factors such as individual ERP wavelengths, the influence of state- and trait-based variation on MM training outcomes, and the heterogeneity of human neurocognition are to be factored by future studies.

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List of Appendices

Appendix A

Study Recruitment Flyer

Meditation study

Recruitment flyer:

Can practicing mediation or relaxation improve attention??

UTAS Cog Neuro Lab are looking at the effects of meditation/relaxation practice on attention. The research involves two experimental sessions one week apart (each 2 hours), and practicing meditation or relaxation using a mobile phone 'app' during the week in between (20 mins per day for 7 days). During the experimental sessions, you will complete some attention tasks on a computer while we measure your brain activity.

We are looking for adults (18-35 years) who don't currently meditate or play lots of video games, with no serious physical, mental, neurological conditions, or medication/drug use.

Reimbursement: $60 giftpay voucher (or $20 voucher and 4 hours research participation for Psychology students)

Head to < insert screening survey link > for more info and to complete the screening survey.

Or contact < enter email address > with any questions.

Social Media:

UTAS Cog Neuro Lab are looking at the effects of meditation and relaxation practice on attention. The research involves two experimental sessions one week apart (each 2 hours), and practicing meditation or relaxation using an 'app' in the week

between (20 mins per day for 7 days). We are looking for adults (18-35 years) who don't currently meditate. Reimbursement: $60 giftpay voucher (or $20 voucher and 4 hours research participation for psychology students). Head to < insert screening survey link > for more info and to complete the screening survey. Or contact < enter email address > with any questions.

Video Game Study

Recruitment flyer:

Can playing video games improve attention??

UTAS Cog Neuro Lab are looking at the effects of video games on attention. The research involves two experimental sessions one week apart (each 2 hours), and practicing video games during the week in between (20 mins per day for 7 days). During the experimental sessions, you will complete some attention tasks on a computer while we measure your brain activity.

We are looking for adults (18-35 years) who don't currently meditate or play lots of video games, with no serious physical, mental, neurological conditions, or medication/drug use.

Reimbursement: $60 giftpay voucher (or $20 voucher and 4 hours research participation for Psychology students)

Head to < insert screening survey link > for more info and to complete the screening survey.

Or contact < enter email address > with any questions.

Social Media:

UTAS Cog Neuro Lab are looking at the effects of video games on attention. The research involves two experimental sessions one week apart (each 2 hours), and practicing video games during the week in between (20 mins per day for 7 days). We are looking for adults (18-35 years) who don't play lots of video games. Reimbursement: $60 giftpay voucher (or $20 voucher and 4 hours research participation for psychology students). Head to < insert screening survey link > for more info and to complete the screening survey. Or contact < enter email address > with any questions.

Appendix B

Training Protocol for Mindfulness Meditation Intervention

Instructions – Mindfulness/Muse

1. Locate yourself in a quiet room where you won't be distracted.
2. Sit down on a comfortable chair or cushion with your back straight. You can sit with your legs crossed or out in front of you, and you can wrap a blanket around you for warmth and comfort if you wish.
3. Ensure the Muse headband is **fully charged** by tapping the power button to display power level [look for 5 lights].
4. Open the **Muse app** on your phone
5. Login with your account.
6. Place the Muse headband over your ears and forehead.
7. On the 'Meditate' screen, ensure the following options are selected:
    a. **Length:** 10 or 20 minutes (depending on the day)
    b. **Soundscape:** Rainforest
    c. **Exercise:** Intro to Muse.
        i. **Note:** You can find 'Intro to Muse' within the **Muse Essentials** option. This study will progress through the **10** Muse Essentials courses.
        ii. See the **'Daily Task Schedule'** below for details on which course you should choose on which day and the duration.
8. **Calibration** will then begin. Listen to the instructions and adjust the headband as necessary.
9. Listen to the audio instructions. It is important that you listen to the entire instructions (although you don't need to listen to the instructions for every new session).
10. Click "Skip to results"
11. Click "Save".

Each day for 7 days, complete **the following sessions.**

Daily Task Schedule:

Day 1:	**Day 2:**
Intro to Muse (10 minutes)	Sensation of Breath (10 minutes)
Training a Puppy (10 minutes)	Counting Breaths (10 minutes)

Day 3:
Sitting Comfortably (10 minutes)
Finding your Soundscape (10 minutes)

Day 4:
Dealing with Distraction (20 minutes)

Day 5:
Working with Discomfort (20 minutes)

Day 6:
Lowering the Bar (20 minutes)

Day 7:
Bridging to Daily Life (20 minutes)

Trouble shooting

If you are having **issues connecting** your phone with the Muse headband:

- Make sure location is enabled on the phone or tablet
- If you are using/intend to use Apple AirPods, make sure those are connected before connecting the headband
- If 'Problems Connecting' appears, tap on the prompt and select the corresponding headband device.
- User guide for further troubleshooting is available at https://tinyurl.com/MuserGuide

---

If anything goes wrong (e.g. the app or device won't work, calibration won't work, etc.) or if you have any questions at all, please contact any of the following researchers

James Brady
Ph: 04.....
Email: james.brady@utas.edu.au

Bronte Matthews
Ph: 04.....
Email: brontem2@utas.edu.au

Safety Information

- In rare cases, people experience seizures or blackouts due to exposure to flashing lights and patterns created by the display of certain applications on mobile or other such similar devices.
- If you have done so, or have experienced any nausea, involuntary movements, tingling, numbness, or vision issues while using such devices in the past, you should consult with your doctor before using similar applications and should immediately cease all such use of such applications should the symptoms re-occur.
- In any event you should avoid prolonged use of such applications to minimize any possible discomfort or fatigue, including any muscle, joint or eye strain and should closely monitor your children's use of technology to avoid possible problems.

Hardware Safety

- Do not dispose of MUSE into fire or hot oven, or mechanically crush or cut the MUSE or the battery contained within, as this may result in an explosion.
- Do not expose the MUSE to an extremely high temperature environment, as this may result in an explosion or the leaking of flammable liquid or gas.
- Do not expose the MUSE to extremely low air pressure, as that may result in an explosion or the leakage of flammable liquid or gas.

Appendix C

Training Protocol for Relaxation Control

Instructions – Relaxation/PIP

1. Locate yourself in a quiet room where you won't be distracted.
2. Sit down on a comfortable chair or cushion with your back straight. You can sit with your legs crossed or out in front of you, and you can wrap a blanket around you for warmth and comfort if you wish.
3. Ensure your mobile phone's **Bluetooth connectivity** option is enabled.
4. Ensure the Pip device is **fully charged.** Plug Pip into a USB outlet and ensure the red light is no longer on [fully charged]
5. Hold the Pip's sensor between your thumb and forefinger and let go, holding and releasing (each for 1 second at a time) until a green light flashes.
6. Open the '**Loom'** app on your mobile phone
7. Click 'settings' in the top right-hand corner of the home screen and change **session length** to '**Long'** and ensure **Music** is **'On'.**
8. Select '**New session'** in the Loom menu
9. **Install** the additional pictures **'Awaken'** and **'Enchanted forest'** in the Loomscape option menu (this will require WiFi or internet connection).
10. Check that phone's audio is turned on.
11. Begin relaxing!

Each day for 7 days, complete **the following sessions.** Your sessions should sum to approximately **20 minutes** per day. If the first session takes longer than 15 minutes, choose another short or medium session to complete so that you complete approximately 20mins. Similarly, if the two sessions take less than 20 minutes, choose another short or medium session to make the time up to approx. 20 minutes.

Daily Task Schedule:

Day 1:
New life (long session)
Awaken (long session)

Day 2:
Enchanted forest (long session)
New life (long session)

Day 3:
Awaken (long session)
Enchanted forest (long session)

Day 4:
New life (long session)
Awaken (long session)

Day 5:
Enchanted forest (long session)
New life (long session)

Day 6:	**Day 7:**
Awaken (long session) Enchanted forest (long session)	Choose any two long sessions to complete

Trouble shooting

If you start a session, and after a few minutes there is no progress (i.e., no change in the visual scene or the progress bar at the bottom of the screen is not changing from blue to green), you could try stopping and restarting the session, or reconnecting or re-pairing the pip device (see below).

Re-connecting the device

Go to 'Menu', Click 'devices', click 'disconnect'

Then click 'reconnect'

Re-pairing the device

Go to 'Menu', Click 'devices', click 'delete' and then ok

Click 'new pip', and then 'start

Follow the instructions: Grip the Pip's sensor and let go, holding and releasing (each for 1 second at a time) until a green light flashes.

Click 'connect to bluetooth'

Select 'New Session' in the Loom menu.

If anything goes wrong (e.g. the app or device won't work etc.) or if you have any questions at all, please contact any of the following researchers:

James Brady
Ph: 0488 662 396
Email: james.brady@utas.edu.au

Email: brontem2@utas.edu.au

Bronte Matthews
Ph: 0439 844 973

Safety Information

Battery

- Pip contains a lithium-polymer battery.
- Charge the battery only with the supplied micro USB charging cable. Do not attempt to remove the battery.
- The lithium-polymer battery might present a fire or chemical burn hazard or might explode if mistreated.
- Do not attempt to disassemble, crush, or puncture the battery.
- Do not heat the battery above 60 degrees Celcius.

Caution

- This device and its antenna(s) must not be co-located or operating in conjunction with any other antenna or transmitter.

Appendix D

Ethics Approval

UNIVERSITY of TASMANIA

07 June 2019

Dr Allison Matthews
C/- Psychology, UTAS

Sent via email

Dear Dr Matthews

REF NO: H0017994
TITLE: The Effects of Video Games and Mindfulness Meditation on Neural Correlates of Attention

Document	*Version*	*Date*
Human Research Ethics Application	v2	
Study Protocol	v2	13May2019
Participant Information Sheet and Consent Form	v2	15May2019
Muse End User License Agreement Terms of Service		
Pip End User License Agreement Terms of Service		

The Tasmania Health and Medical Human Research Ethics Committee (HREC) considered and approved the above documentation on **21 May 2019** to be conducted at the following site(s):

University of Tasmania

Please ensure that all investigators involved with this project have cited the approved versions of the documents listed within this letter and use only these versions in conducting this research project.

This approval constitutes ethical clearance by the Health and Medical HREC. The decision and authority to commence the associated research may be dependent on factors beyond the remit of the ethics review process. For example, your research may need ethics clearance from other organisations or review by your research governance coordinator or Head of Department. It is your responsibility to find out if the approvals of other bodies or authorities are required. It is recommended that the proposed research should not commence until you have satisfied these requirements.

In accordance with the National Statement on Ethical Conduct in Human Research, it is the responsibility of institutions and researchers to be aware of both general and specific legal requirements, wherever relevant. If researchers are uncertain they should seek legal advice

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to confirm that their proposed research is in compliant with the relevant laws. University of Tasmania researchers may seek legal advice from Legal Services at the University.

All committees operating under the Human Research Ethics Committee (Tasmania) Network are registered and required to comply with the *National Statement on the Ethical Conduct in Human Research* (NHMRC 2007 updated 2018).

Therefore, the Chief Investigator's responsibility is to ensure that:

(1) All investigators are aware of the terms of approval, and that the research is conducted in compliance with the HREC approved protocol or project description.

(2) Modifications to the protocol do not proceed until **approval** is obtained in writing from the HREC. This includes, but is not limited to, amendments that:

(i) are proposed or undertaken in order to eliminate immediate risks to participants;
(ii) may increase the risks to participants;
(iii) significantly affect the conduct of the research; or
(iv) involve changes to investigator involvement with the project.

Please note that all requests for changes to approved documents must include a version number and date when submitted for review by the HREC.

(3) Reports are provided to the HREC on the progress of the research and any safety reports or monitoring requirements as indicated in NHMRC guidance. The appropriate forms for reporting such events in relation to clinical and non-clinical trials and innovations can be located at the website below. All adverse events must be reported regardless of whether or not the event, in your opinion, is a direct effect of the therapeutic goods being tested. http://www.utas.edu.au/research-admin/research-integrity-and-ethics-unit-rieu/human-ethics/human-research-ethics-review-process/health-and-medical-hrec/managing-your-approved-project

(4) The HREC is informed as soon as possible of any new safety information, from other published or unpublished research, that may have an impact on the continued ethical acceptability of the research or that may indicate the need for modification of the project.

(5) All research participants must be provided with the current Participant Information Sheet and Consent Form, unless otherwise approved by the Committee.

(6) This study has approval for four years contingent upon annual review. A *Progress Report* is to be provided on the anniversary date of your approval. Your first report is due **21 May 2020,** and you will be sent a courtesy reminder closer to this due date. Ethical approval for this project will lapse if a Progress Report is not submitted in the time frame provided

(7) A *Final Report* and a copy of the published material, either in full or abstract, must be provided at the end of the project.

(8) The HREC is advised of any complaints received or ethical issues that arise during the course of the project.

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(9) The HREC is advised promptly of the emergence of circumstances where a court, law enforcement agency or regulator seeks to compel the release of findings or results. Researchers must develop a strategy for addressing this and seek advice from the HREC.

Should you have any queries please do not hesitate to contact me on (03) 6226 6254 or via email Human.ethics@utas.edu.au.

Yours sincerely

Ailin Ding
Administration Officer

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Appendix E

Online Screening Questionnaire

By clicking next, you are signalling your consent to complete the screening survey, and if contacted, you will be free to decide whether you would like to participate in the study. You are also free to decline to answer any questions. However, researchers may call or email to clarify any missing answers prior to confirming eligibility.

Demographics
Please enter your first name _____.
Please enter your email address _____.
Please enter your phone number _____.
How old are you? _____.
What is your biological sex? Male: ☐ Female: ☐ No answer: ☐
Are you right or left handed? Right: ☐ Left: ☐ No answer: ☐
Is English your first language? Y: ☐ N: ☐ No answer: ☐
Are you currently pregnant or could be pregnant? Y: ☐ N: ☐ No answer: ☐
Health
Do you have sensitive skin? Y: ☐ N: ☐ No answer: ☐
Have you ever experienced (or been diagnosed with) any of the following:
Epilepsy Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Fits / seizures Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Regular giddiness/fainting Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Severe / multiple concussions Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Severe head injury Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Brain surgery Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Loss of consciousness (more than 2 minutes) Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Diabetes Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Heart Condition Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐

Sleep disorder (or any major sleeping difficulties) Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Visual problems (not corrected by glasses/lenses) Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Auditory problems Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Any other serious physical condition Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Any other neurological condition Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
ADHD/ADD Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Dyslexia Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Learning difficulties Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Current depression / anxiety Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Past depression / anxiety Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Other mental health conditions (e.g., mania, psychosis, schizophrenia, PTSD, OCD, substance dependence etc) Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐

If you answered yes or uncertain to any of the above, please provide some brief details (or the researchers can ask by phone if you prefer):

_____

Are you currently taking any prescribed medications? Y: ☐ N: ☐ No answer: ☐

If yes, please list the name of the medications:

_____

_____

_____.

Substance use

The following questions are about your use of tobacco and alcohol

In the last 6 months, how often have you used tobacco/nicotine?

Never 0
Less than monthly 1
Monthly 2
Weekly 3
Daily or almost daily 4

AUDIT

Q1. How often do you have a drink containing alcohol?

Never.....0
(Go to Q9)
Monthly or less.....1
2–4 times per month.....2
2–3 times per week.....3
4 or more times a week.....4

Q2. How many drinks containing alcohol do you have on a typical day when you are drinking?

1 or 2.....0
3 or 4.....1
5 or 6.....2
7 to 9.....3
10 or more 4

Q3. How often do you have six or more drinks on one occasion?

Never.....0
Less than monthly.....1
Monthly.....2
Weekly 3
Daily or almost daily 4

Q4. How often during the last year have you found that you were unable to stop drinking once you had started?

Never.....0
Less than monthly.....1
Monthly.....2
Weekly 3
Daily or almost daily 4

Q5. How often during the last year have you failed to do what was normally expected from you because of drinking?

Never.....0
Less than monthly.....1
Monthly.....2
Weekly 3
Daily or almost daily 4

Q6. How often during the last year have you needed a first drink in the morning to get yourself going, after a heavy drinking section?

Never.....0
Less than monthly.....1
Monthly.....2
Weekly 3
Daily or almost daily 4

Q7. How often during the last year have you had a feeling of guilt or remorse after drinking?

Never.....0
Less than monthly.....1
Monthly.....2
Weekly 3
Daily or almost daily 4

Q8. How often during the last year have you been unable to remember what happened the night before because you had been drinking?

Never.....
.....0
Less than
monthly.....1
Monthly.....
.....2
Weekly
.....3
Daily or almost daily
.....4

Q9. Have you or someone else been injured as a result of your drinking?
No.....
.....0
Yes, but not in the last year
.....2
Yes, during the last year
.....4

Q10. Has a relative or friend or doctor or other health worker been concerned about your drinking or suggested you cut down?
No.....
.....0
Yes, but not in the last year
.....2
Yes, during the last year
.....4

Kessler Psychological Distress scale

(K10)

In the last 4 weeks, about how often:

1. Did you feel tired out for no good reason?

All of the time.....1
Most of the time.....2
Some of the time.....3
A little of the time.....4
None of the time 5

2. Did you feel nervous?

All of the time.....1
Most of the time.....2
Some of the time.....3
A little of the time.....4
None of the time 5

Note: If response 5 chosen, go to Q4

3. Did you feel so nervous that nothing could calm you down?

All of the time.....1
Most of the time.....2
Some of the time.....3
A little of the time.....4
None of the time 5

4. Did you feel hopeless?

All of the time.....1
Most of the time.....2
Some of the time.....3
A little of the time.....4
None of the time 5

5. Did you feel restless or fidgety?

All of the time.....1
Most of the time.....2
Some of the time.....3
A little of the time.....4
None of the time 5

Note: If response 5 chosen, go to Q7

6. Did you feel so restless that you could not sit still?

All of the time.....1
Most of the time.....2
Some of the time.....3
A little of the time.....4
None of the time.....5

7. Did you feel depressed?

All of the time.....1
Most of the time.....2

Some of the time.....3
A little of the time.....4
None of the time.....5

8. Did you feel that everything was an effort?
All of the time.....1
Most of the time.....2
Some of the time.....3
A little of the time.....4
None of the time 5

9. Did you feel so sad that nothing could cheer you up?
All of the time.....1
Most of the time.....2
Some of the time.....3
A little of the time.....4
None of the time 5

10. Did you feel worthless?
All of the time.....1
Most of the time.....2
Some of the time.....3
A little of the time.....4
None of the time 5

STAI - Trait Anxiety

SELF-EVALUATION QUESTIONNAIRE

STAI Form Y-2

Name_____ Date_____

DIRECTIONS

A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate value to the right of the statement to indicate how you *generally* feel. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe how you generally feel.

	ALMOST NEVER	SOMETIMES	OFTEN	ALMOST ALWAYS
21. I feel pleasant	1	2	3	4
22. I feel nervous and restless	1	2	3	4
23. I feel satisfied with myself	1	2	3	4
24. I wish I could be as happy as others seem to be	1	2	3	4
25. I feel like a failure	1	2	3	4
26. I feel rested	1	2	3	4
27. I am "calm, cool, and collected"	1	2	3	4
28. I feel that difficulties are piling up so that I cannot overcome them	1	2	3	4
29. I worry too much over something that really doesn't matter	1	2	3	4
30. I am happy	1	2	3	4
31. I have disturbing thoughts	1	2	3	4
32. I lack self-confidence	1	2	3	4
33. I feel secure	1	2	3	4
34. I make decisions easily	1	2	3	4
35. I feel inadequate	1	2	3	4
36. I am content	1	2	3	4
37. Some unimportant thought runs through my mind and bothers me	1	2	3	4
38. I take disappointments so keenly that I can't put them out of my mind	1	2	3	4
39. I am a steady person	1	2	3	4
40. I get in a state of tension or turmoil as I think over my recent concerns and interests	1	2	3	4

Meditation / Relaxation Experience Questionnaire

Have you had any experience with the following forms of meditation/relaxation?

	Yes	**No**
Mindfulness training (including MBSR MBCBT, IBMT, MiCT, ACT, etc)		
Zen		
Vipassana		
Shamatha		
Vipashyana		
Shavasana		
Meditative contemplation		
Sadhana		
Mahamudra		
Breathing meditation		
Walking meditation		
Compassion meditation (tonglen, metta, loving, kindness, etc.)		
Ngondro		
TM		
Tai Chi		
Yoga		
Qigong		
Relaxation exercises (e.g., progressive muscle relaxation)		
Other…… (please specify)		

In the past year, how much time have you spent practicing any form of meditation / relaxation per week?

None
Less than 15 mins
15-30 mins
30-60 mins
1-2 hours

2-5 hours
More than 5 hours

Which forms of meditation / relaxation have you practiced in the past year?

_____

In your lifetime, how many hours have you spent practicing meditation / relaxation?
None
Less than 1 hours
1-5 hours
5-10 hours
10-20 hours
More than 20 Hours

Which forms of meditation / relaxation have you practiced for more than 5 hours in your lifetime?

_____

FFMQ-15: 15-item Five-Facet Mindfulness Questionnaire

Instructions

Please use the 1 (never or very rarely true) to 5 (very often or always true) scale provided to indicate how true the below statements are of you. Circle the number in the box to the right of each statement which represents your own opinion of what is generally true for you. For example, if you think that a statement is often true of you, circle '4' and if you think a statement is sometimes true of you, circle '3'.

	Never or very rarely true	Rarely true	Sometimes true	Often true	Very often or always true
1. When I take a shower or a bath, I stay alert to the sensations of water on my body.	1	2	3	4	5
2. I'm good at finding words to describe my feelings.	1	2	3	4	5
3. I don't pay attention to what I'm doing because I'm daydreaming, worrying, or otherwise distracted.	1	2	3	4	5
4. I believe some of my thoughts are abnormal or bad and I shouldn't think that way.	1	2	3	4	5
5. When I have distressing thoughts or images, I "step back" and am aware of the thought or image without getting taken over by it.	1	2	3	4	5
6. I notice how foods and drinks affect my thoughts, bodily sensations, and emotions.	1	2	3	4	5
7. I have trouble thinking of the right words to express how I feel about things.	1	2	3	4	5
8. I do jobs or tasks automatically without being aware of what I'm doing.	1	2	3	4	5
9. I think some of my emotions are bad or inappropriate and I shouldn't feel them.	1	2	3	4	5
10. When I have distressing thoughts or images I am able just to notice them without reacting.	1	2	3	4	5
11. I pay attention to sensations, such as the wind in my hair or sun on my face.	1	2	3	4	5
12. Even when I'm feeling terribly upset I can find a way to put it into words.	1	2	3	4	5
13. I find myself doing things without paying attention.	1	2	3	4	5
14. I tell myself I shouldn't be feeling the way I'm feeling.	1	2	3	4	5
15. When I have distressing thoughts or images I just notice them and let them go.	1	2	3	4	5

Baer, R. A., Carmody, J., & Hunsinger, M. (2012). Weekly change in mindfulness and perceived stress in a mindfulness-based stress reduction program. *Journal of Clinical Psychology, 68*(7), 755-765. doi: 10.1002/jclp.21865

Gu, J., Strauss, C., Crane, C., Barnhofer, T., Karl, A., Cavanagh, K., & Kuyken, W. (2016). Examining the factor structure of the 39-item and 15-item versions of the Five Facet Mindfulness Questionnaire before and after mindfulness-based cognitive therapy for people with recurrent depression. *Psychological assessment, 28*(7), 791. doi: 10.1037/pas0000263

The mini International Personality Item Pool (IPIP) scale

Donnellan, M.B., Oswald, F.L., Baird, B.M., & Lucas, R.E. (2006).

Instructions: On the following pages, there are phrases describing people's behaviors. Please use the rating scale below to describe how accurately each statement describes you. Describe yourself as you generally are now, not as you wish to be in the future. Describe yourself as you honestly see yourself, in relation to other people you know of the same sex as you are, and roughly your same age. So that you can describe yourself in an honest manner, your responses will be kept in absolute confidence. Please read each statement carefully, and then fill in the bubble that corresponds to the number on the scale.

1=Very Inaccurate
2=Moderately Inaccurate
3=Neither Inaccurate nor Accurate
4=Moderately Accurate
5=Very Accurate

1. Am the life of the party (E)
2. Sympathize with others' feelings (A)
3. Get chores done right away (C)
4. Have frequent mood swings (N)
5. Have a vivid imagination (I)
6. Don't talk a lot (E)
7. Am not interested in other people's problems (A)
8. Often forget to put things back in their proper place (C)
9. Am relaxed most of the time (N)
10. Am not interested in abstract ideas (I)
11. Talk to a lot of different people at parties (E)
12. Feel others' emotions (A)
13. Like order (C)
14. Get upset easily (N)
15. Have difficulty understanding abstract ideas (I)
16. Keep in the background (E)
17. Am not really interested in others (A)
18. Make a mess of things (C)
19. Seldom feel blue (N)
20. Do not have a good imagination (I)

Note: Items 6, 7, 8, 9, 10, 15, 16, 17, 18, 19, and 20 are reverse scored.

Thank you for completing the screening survey. If you are eligible to participate, the researchers will contact you, and you will be free to choose whether to participate in the experiment.

Please note: If you are feeling distressed, there are list of free counselling services below that you can access free of charge.

Beyond Blue	Lifeline Australia	Mental Health Helpline (TAS)
1300 224 636	13 11 14	1800 332 388
www.beyondblue.org.au	www.lifeline.org.au	
	www.dhhs.tas.gov.au/mentalhealth	

Appendix F

Participant Information Sheet

1. I agree to take part in the research study named above.
2. I have read and understood the Information Sheet for this study.
3. The nature and possible effects of the study have been explained to me.
4. I understand that the study involves:
    - Completion of an online screening survey
    - Attending two experimental sessions (of approximately two hours each) one week apart, during which my brain activity will be recorded while I complete some computer-based tasks, involving pressing buttons in response to words/symbols on a screen.
    - Practicing video games, meditation or relaxation during the week in between the experimental sessions (approximately 20 mins per day for 5 days).
5. I understand that participation involves a slight risk of skin irritation if I have sensitive skin.
6. I have been provided with numbers which I can contact (see Information Sheet) if I have any concerns.
7. I understand that all research data will be securely stored on the University of Tasmania premises for 15 years from the publication of the results, and will then be securely destroyed.
8. Any of my questions have been answered to my satisfaction.
9. I understand that the researcher(s) will maintain confidentiality and that any information I supply to the researcher(s) will be used only for the purposes of the research.
10. I understand that the results of the study will be published as group data, and I will not be identified as a participant.
11. I understand that my participation is voluntary and that I may withdraw at any time without any effect and may request that my data be withdrawn from the research up until 31st August 2019.

Participant's name: _____

Participant's signature: _____Date: _____

Statement by Investigator

☐ I have explained the project and the implications of participation in it to this volunteer and I believe that the consent is informed and that he/she understands the implications of participation

Investigator's name:

_____

Investigator's signature: _____Date:

_____

Appendix G

Experimental Questionnaires

Date ____/____/____ ID Number:_____

Experimental Session Screening Questionnaire
Have you abstained from illicit drugs since first contact from the experimenter? Yes: ☐
Have you consumed alcohol within the last 24 hours? Yes: ☐ No: ☐
How many cups of coffee (or other caffeinated products) have you consumed today? _____. If yes: many hours has it been since your last? _____.
Have you had any tobacco or nicotine products today? Yes: ☐ No: ☐ *If yes:* how many cigarettes / nicotine products have you had today? _____. *If yes:* how many hours since your last cigarette or nicotine product? _____.
Have you consumed any medications in the past week) Yes: ☐ No: ☐ *If yes,* please detail: Medication Estimated dose Number of occasions taken Time since last taken 1. _____ 2. _____ 3. _____ 4. _____ 5. _____
Are you an undergraduate psychology student completing this study for course credit?

Yes: ☐ No: ☐

Karolinska Sleepiness Scale

Please circle on the following scale of 1 to 9 how you feel AT THE PRESENT MOMENT*:*

1. Extremely alert
2. Very alert
3. Alert
4. Rather alert
5. Neither alert nor sleepy
6. Some signs of sleepiness
7. Sleepy, but no effort to keep awake
8. Sleepy, some effort to keep awake
9. Very sleepy, great effort to keep awake, fighting sleep

Profile of Mood States-Short Form

Below is a list of words that describe feelings people have. Please read each one carefully. Then circle ONE answer to the right, which best describes how you are feeling AT THE MOMENT.

The numbers refer to these phrases:
0=not at all
1=a little
2=moderately
3=quite a bit
4= extremely

1. Tense.....0 1 2 3 4
2. Angry.....0 1 2 3 4
3. Worn out.....0 1 2 3 4
4. Unhappy.....0 1 2 3 4
5. Lively.....0 1 2 3 4
6. Confused.....0 1 2 3 4
7. Peeved.....0 1 2 3 4
8. Sad.....0 1 2 3 4
9. Active.....0 1 2 3 4
10. On Edge.....0 1 2 3 4
11. Grouchy.....0 1 2 3 4
12. Blue.....0 1 2 3 4
13. Energetic..... 0 1 2 3 4
14. Hopeless.....0 1 2 3 4
15. Uneasy.....0 1 2 3 4
16. Restless.....0 1 2 3 4
17. Unable to Concentrate.....0 1 2 3 4
18. Fatigued.....0 1 2 3 4
19. Annoyed.....0 1 2 3 4
20. Discouraged.....0 1 2 3 4
21. Resentful.....0 1 2 3 4
22. Nervous.....0 1 2 3 4
23. Miserable.....0 1 2 3 4
24. Cheerful.....0 1 2 3 4
25. Bitter.....0 1 2 3 4
26. Exhausted.....0 1 2 3 4
27. Anxious.....0 1 2 3 4
28. Helpless.....0 1 2 3 4
29. Weary.....0 1 2 3 4
30. Bewildered.....0 1 2 3 4
31. Furious.....0 1 2 3 4
32. Full of pep.....0 1 2 3 4
33. Worthless.....0 1 2 3 4
34. Forgetful.....0 1 2 3 4
35. Vigorous.....0 1 2 3 4
36. Uncertain about things.....0 1 2 3 4
37. Bushed.....0 1 2 3 4

The Cognitive and Affective Mindfulness Scale – Revised (CAMS-R)

The CAMS-R is a 12-item measure designed to capture a broad conceptualization of mindfulness with language that is not specific to any particular type of meditation training.

Feldman, G., Hayes, A., Kumar, S. et al. J Psychopathol Behav Assess (2007) 29: 177. doi:10.1007/s10862-006-9035-8

Instructions: People have a variety of ways of relating to their thoughts and feelings. For each of the items below, rate how much each of these ways applies to *you*.

_____ 1. It is easy for me to concentrate on what I am doing.
_____ 2. I am preoccupied by the future.
_____ 3. I can tolerate emotional pain.
_____ 4. I can accept things I cannot change.
_____ 5. I can usually describe how I feel at the moment in considerable detail.
_____ 6. I am easily distracted.
_____ 7. I am preoccupied by the past.
_____ 8. It's easy for me to keep track of my thoughts and feelings.
_____ 9. I try to notice my thoughts without judging them.
_____ 10. I am able to accept the thoughts and feelings I have.
_____ 11. I am able to focus on the present moment.
_____ 12. I am able to pay close attention to one thing for a long period of time.

Scoring: Items 2, 6, and 7 are reverse-scored. After appropriate reversals, sum values for items 1 - 12. Higher values reflect greater mindful qualities.

The Mindful Attention Awareness Scale (MAAS)

The trait MAAS is a 15-item scale designed to assess a core characteristic of mindfulness, namely, a receptive state of mind in which attention, informed by a sensitive awareness of what is occurring in the present, simply observes what is taking place.

Brown, K.W. & Ryan, R.M. (2003). The benefits of being present: Mindfulness and its role in psychological well-being. *Journal of Personality and Social Psychology, 84,* 822-848.

Carlson, L.E. & Brown, K.W. (2005). Validation of the Mindful Attention Awareness Scale in a cancer population. *Journal of Psychosomatic Research, 58,* 29-33.

Instructions: Below is a collection of statements about your everyday experience. Using the 1-6 scale below, please indicate how frequently or infrequently you currently have each experience. Please answer according to what really reflects your experience rather than what you think your experience should be. Please treat each item separately from every other item.

1	2	3	4	5	6
almost always	very frequently	somewhat frequently	somewhat infrequently	very infrequently	almost never

_____ 1. I could be experiencing some emotion and not be conscious of it until some time later.
_____ 2. I break or spill things because of carelessness, not paying attention, or thinking of something else.
_____ 3. I find it difficult to stay focused on what's happening in the present.
_____ 4. I tend to walk quickly to get where I'm going without paying attention to what I experience along the way.
_____ 5. I tend not to notice feelings of physical tension or discomfort until they really grab my attention.
_____ 6. I forget a person's name almost as soon as I've been told it for the first time.
_____ 7. It seems I am "running on automatic," without much awareness of what I'm doing.
_____ 8. I rush through activities without being really attentive to them.
_____ 9. I get so focused on the goal I want to achieve that I lose touch with what I'm doing right now to get there.
_____ 10. I do jobs or tasks automatically, without being aware of what I'm doing.
_____ 11. I find myself listening to someone with one ear, doing something else at the same time.
_____ 12. I drive places on 'automatic pilot' and then wonder why I went there.
_____ 13. I find myself preoccupied with the future or the past.
_____ 14. I find myself doing things without paying attention.
_____ 15. I snack without being aware that I'm eating.

Scoring: To score the scale, simply compute a mean (average) of the 15 items.

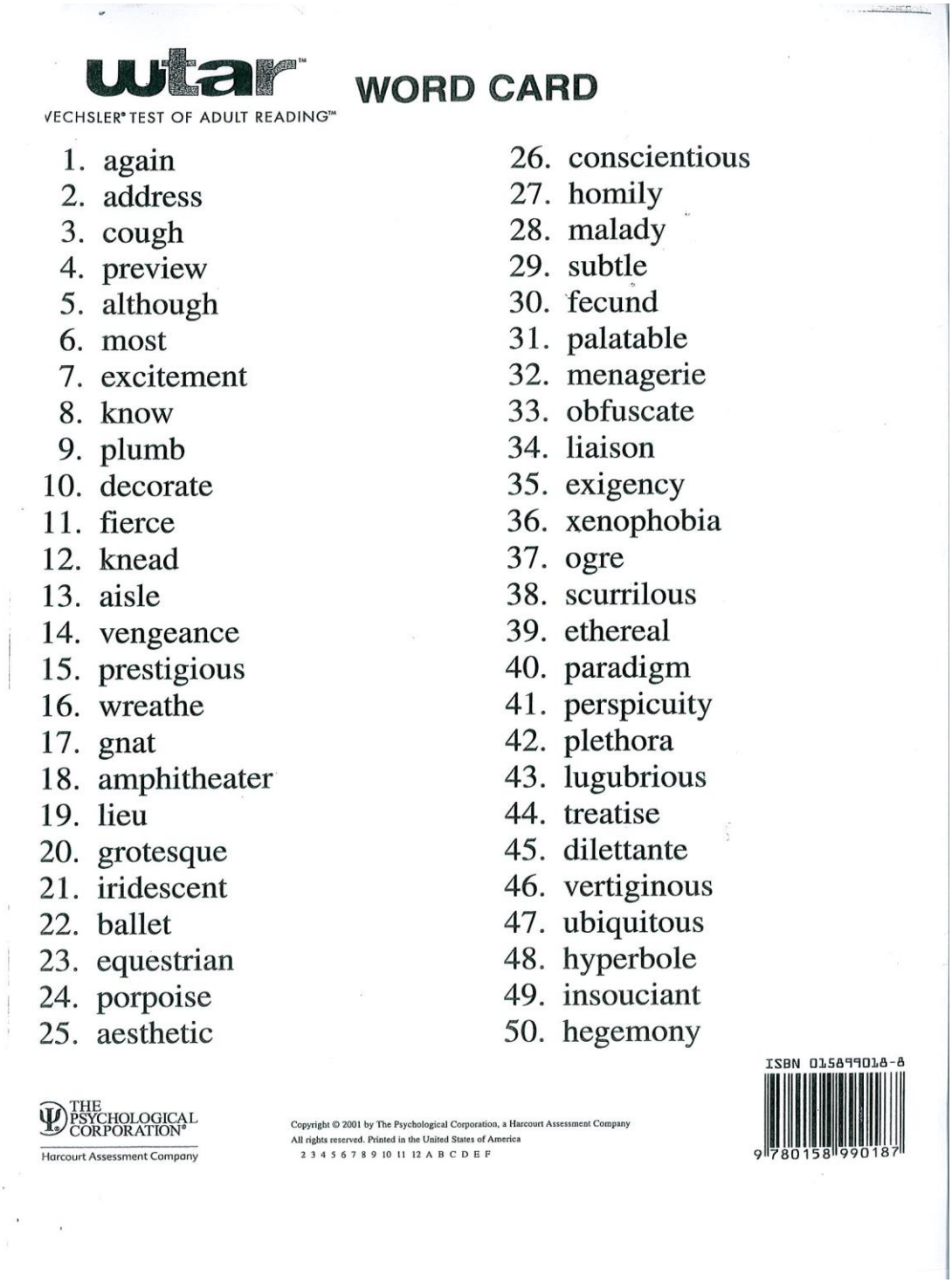
DERS-18

Response categories:

1	2	3	4	5
Almost Never (0-10%)	Sometimes (11-35%)	About Half the Time (36-65%)	Most of the Time (66-90%)	Almost Always (91-100%)

1. _____ I pay attention to how I feel.
2. _____ I have no idea how I am feeling.
3. _____ I have difficulty making sense out of my feelings.
4. _____ I am attentive to my feelings.
5. _____ I am confused about how I feel.
6. _____ When I'm upset, I acknowledge my emotions.
7. _____ When I'm upset, I become embarrassed for feeling that way.
8. _____ When I'm upset, I have difficulty getting work done.
9. _____ When I'm upset, I become out of control.
10. _____ When I'm upset, I believe that I will remain that way for a long time.
11. _____ When I'm upset, I believe that I'll end up feeling very depressed.
12. _____ When I'm upset, I have difficulty focusing on other things.
13. _____ When I'm upset, I feel ashamed with myself for feeling that way.
14. _____ When I'm upset, I feel guilty for feeling that way.
15. _____ When I'm upset, I have difficulty concentrating.
16. _____ When I'm upset, I have difficulty controlling my behaviors.
17. _____ When I'm upset, I believe that wallowing in it is all I can do.
18. _____ When I'm upset, I lose control over my behaviors.

Weschler test of Adult Reading (WTAR) – Pre-training only



wtar™

WECHSLER® TEST OF ADULT READING™

WORD CARD

1. again
2. address
3. cough
4. preview
5. although
6. most
7. excitement
8. know
9. plumb
10. decorate
11. fierce
12. knead
13. aisle
14. vengeance
15. prestigious
16. wreathe
17. gnat
18. amphitheater
19. lieu
20. grotesque
21. iridescent
22. ballet
23. equestrian
24. porpoise
25. aesthetic
26. conscientious
27. homily
28. malady
29. subtle
30. fecund
31. palatable
32. menagerie
33. obfuscate
34. liaison
35. exigency
36. xenophobia
37. ogre
38. scurrilous
39. ethereal
40. paradigm
41. perspicuity
42. plethora
43. lugubrious
44. treatise
45. dilettante
46. vertiginous
47. ubiquitous
48. hyperbole
49. insouciant
50. hegemony

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ID Number: _____ Session: _____Time: pre / post

Please read each word carefully and draw a mark on each line indicating how you feel at THE PRESENT MOMENT:

1. **Alert**
   STRONGLY AGREE _____ STRONGLY DISAGREE

2. **Distracted**
   STRONGLY AGREE _____ STRONGLY DISAGREE

3. **Calm**
   STRONGLY AGREE _____ STRONGLY DISAGREE

4. **Stressed**
   STRONGLY AGREE _____ STRONGLY DISAGREE

5. **Accepting**
   STRONGLY AGREE _____ STRONGLY DISAGREE

6. **Aware**
   STRONGLY AGREE _____ STRONGLY DISAGREE

7. **Present-Focused**
   STRONGLY AGREE _____ STRONGLY DISAGREE

8. **Disinterested**
   STRONGLY AGREE _____ STRONGLY DISAGREE

9. **Fatigued**
   STRONGLY AGREE _____ STRONGLY DISAGREE

10. **Attentive**

STRONGLY AGREE ——— STRONGLY DISAGREE

ID Number: _____

Training Outcome Questionnaire

Now that you have received instructions on the training task that you will complete over the next week, please answer the following questions:

	1 Not at all	2	3	4	5 Somewhat	6	7	8	9 Very much
Do you think this training is likely to improve your attention?									
Do you think this training is likely to improve your ability to complete the computer tasks?									
Do you think this training is likely to improve your emotional wellbeing?									